NATIONAL SCIENCE FOUNDATION

FY 2017 Budget Request to Congress

February 9, 2016

About the Cover:
This cover shows two of the winning images from The Vizzies Visualization Challenge. The images are (top): a photograph of microscopic crystals found in a sea urchin's tooth, and (bottom) an image showing the connectivity of a cognitive computer based on the macaque brain.

For more information see: www.nsf.gov/news/special_reports/scivis/

Image credits: Pupa U. P. A. Gilbert and Christopher E. Killian, University of Wisconsin, Madison (top); Emmett McQuinn, Theodore M. Wong, Pallab Datta, Myron D. Flickner, Raghavendra Singh, Steven K. Esser, Rathinakumar Appuswamy, William P. Risk, and Dharmendra S. Modha (bottom)

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*The National Science Foundation Act of 1950 (Public Law 81-507) sets forth our mission: "**To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense...**"*

*The National Science Foundation Strategic Plan for 2014-2018, "Investing in Science, Engineering, and Education for the Nation's Future," defines our vision: "**A Nation that creates and exploits new concepts in science and engineering and provides global leadership in research and education.**"*

This FY 2017 Budget Request for the National Science Foundation (NSF) continues NSF's longstanding commitment to supporting research that drives scientific discovery, maintains America's global competitiveness, and builds the modern workforce that is critical for addressing the complex challenges that face the Nation. NSF is vital because we invest in basic research and people who make the discoveries that transform our future. Those discoveries are a primary driver of the U.S. economy, enhance our Nation's security, and give the country the competitive edge to remain a global leader.

NSF's FY 2017 Budget Request is $7.964 billion, an increase of $500.53 million (6.7 percent) over the FY 2016 Estimate. This includes $7.56 billion in discretionary budget authority and $400 million in new mandatory budget authority. The FY 2017 Budget Request reflects a carefully chosen portfolio that supports the fundamental research that is NSF's hallmark and creates and sustains key partnerships with other federal agencies, industry, and international entities. Through sustained, longstanding investments in all areas of science, engineering, and education, this submission ensures a robust return on investment for all American citizens.

FY 2017 Budget Request

Total:	$7.964 billion
Increase:	$500.53 million

6.7% over FY 2016

NSF's broad portfolio positions the agency to contribute productively and rapidly to important national challenges. For example, the Computer Science for All initiative, announced by the President on January 30, 2016, builds on ongoing NSF activities that foster rigorous and engaging computer science education in schools across the Nation. Similarly, a range of NSF-supported advances and innovations will help to launch the Administration's cancer "moonshot." These include fundamental research in biology, biochemistry, biophysics; data-driven discovery enabled by machine learning techniques and leveraging NSF-cyberinfrastructure; and engineered systems in nanotechnology, imaging, material science and robotics.

FY 2017 Major Emphases

NSF's FY 2017 Budget Request includes two areas of major emphasis: Clean Energy R&D and strengthening support for core activities, with a special focus on support for early career investigators.

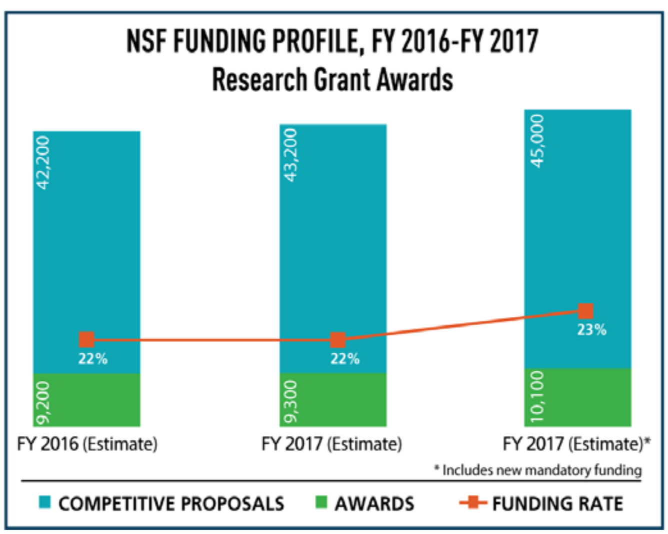
The President joined other world leaders at the recent Paris climate negotiations to launch Mission Innovation, a landmark commitment to dramatically accelerate public and private global clean energy innovation, by investing in new technologies that will define a clean, affordable, and reliable global power mix. Through this initiative, the U.S. and 19 other countries have committed to doubling their governmental clean energy research and development investment over five years. Successful innovation in clean energy requires broad participation, including nontraditional approaches and innovators close to stakeholders that will benefit from clean energy solutions. Mission Innovation provides a robust framework to expand and better integrate clean energy research across agencies. The Budget for NSF includes $512.22 million for investments in Clean Energy R&D. NSF's clean energy portfolio supports research and education in innovative renewable and alternative energy sources for electricity (solar, wind, wave, geothermal) and fuels (chemical and biofuels). NSF funding also addresses the collection, conversion, storage, and distribution of energy from diverse power sources, including smart grids; the science and engineering of energy materials; and energy use and efficiency, including for computing systems. Clean energy research addresses our advancement toward reliable and sustainable energy resources and systems that preserve essential ecosystems and environmental services, promote positive social and economic outcomes, and prepare society to responsibly adopt them.

Funding for FY 2017 Clean Energy R&D

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate	
				Amount	Percent
Clean Energy R&D	$356.02	$371.45	$512.22	$140.77	37.9%

New one-year mandatory funding totaling $400 million will support the fundamental, curiosity-driven research that is NSF's principal contribution to the Nation's science and technology enterprise. In particular, this funding will support more scientists and engineers at the early stages of their careers – who bring particular expertise in data- and computationally-intensive activities – to quicken the pace of discovery and advance the leading edge of research and education. This funding will allow for an estimated 800 additional research grants to be made from a pool of highly-rated proposals that would otherwise be declined for lack of funding. This additional funding would bring NSF's FY 2017 funding rate to an estimated 23 percent.



FY 2017 Cross-Foundation Investments

NSF continues to bring together researchers from all fields of science and engineering to address today's cross-disciplinary questions and challenges through Foundation-wide activities. In FY 2017, NSF continues to support its four FY 2016 cross-foundation investments.

Funding for FY 2017 Cross-Foundation Investments

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	Percent
Understanding The Brain (UtB)	$109.39	$146.93	$141.62	-$5.31	-3.6%
Risk and Resilience	19.34	41.15	43.15	2.00	4.9%
Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)	-	48.68	62.18	13.50	27.7%
Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	-	15.50	16.00	0.50	3.2%

Understanding the Brain (UtB) encompasses ongoing cognitive science and neuroscience research and NSF's contributions to the Administration's Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative. The goal of UtB is to enable scientific understanding of the full complexity of the brain in action and in context. Priorities include: brain-inspired concepts and designs; development of innovative technologies, tools and instrumentation, computational infrastructure, theory, and models to understand the brain; identification of the fundamental relationships among neural activity, cognition, and behavior; understanding how the brain responds and adapts to changing environments and recovers from lost functionality; and BRAIN workforce development and training for the next generation of neuroscientists and neuroengineers. Improved understanding of the brain will promote brain health; enable engineered solutions that enhance, replace or compensate for lost function; improve the effectiveness of formal and informal educational approaches; and lead to brain-inspired smarter technologies for improved quality of life. Basic research in these areas will also offer novel insights into how cognitive abilities develop and can be maintained and improved throughout the lifespan.

NSF In Action

NSF has already helped lay the groundwork for BRAIN by supporting innovations in brain research, including the development of optogenetics, a bioengineering technique that enables scientists to selectively turn on and off particular neurons and neuronal circuits in living organisms; the resulting behavioral changes can be observed in real time. Researchers are using optogenetics to help identify the functions of neurons and neuronal circuits and appropriate targets for drugs or technologies that address brain dysfunction related to conditions such as Parkinson's disease. A crucial prerequisite to the development of optogenetics was a discovery of light-sensitive algae proteins. This pivotal application of algae research to neuroscience underscores the importance to BRAIN of NSF-funded research — including basic research in seemingly far-flung disciplines.

Risk and Resilience investments aim to improve predictability and risk assessment and increase preparedness for extreme natural and man-made events in order to reduce their impact on quality of life, society, and the economy. NSF is uniquely positioned to support such improvements that require multidisciplinary expertise in science, engineering, and education, such as understanding the dynamic processes that produce extreme events, how people respond to extreme events, and how to engineer resilient infrastructure, including in the context of smart and connected communities. One supporting program is Critical Resilient Interdependent Infrastructure Systems and Processes, which directly addresses the need for the resilient and reliable infrastructure that is critical to U.S. economic competitiveness and national security. Another is Prediction of and Resilience against Extreme Events, which aims to enhance the understanding and prediction of, as well as resilience and sustainable responses to, extreme events and geohazards, and their impact on natural and human systems.

NSF In Action

A team of engineers from across the country designed and carried out a series of large-scale tests to better understand exactly what happens when debris carried by tsunamis strikes buildings and other structures. The research ultimately seeks to improve building designs so structures can withstand the force of fast-moving tsunami debris, which can include large objects such as telephone poles or even other buildings. The ambitious project was a collaboration of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) large-scale structures test facility at Lehigh University, the NEES Tsunami Research Facility at Oregon State University, and researchers at the University of Hawaii.

Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) is an NSF-wide investment that aims to understand, design, and model the interconnected food, energy, and water system through an interdisciplinary research effort that incorporates all areas of science and engineering and addresses the natural, social, and human-built factors involved. Throughout NSF, activities address food, energy, or water, such as Water Sustainability and Climate and Hazards; Coupled Natural and Human Systems; and Basic Research to Enable Agricultural Development. INFEWS, however, is the first program to study the interconnected food-energy-water nexus. The need for this program is increasingly urgent, as growing U.S. and global populations, changes in land use, and increasing geographic and seasonal variability in precipitation patterns are placing an ever-increasing stress on these critical resources. NSF, through INFEWS, is uniquely poised to focus not only on the fundamental science and engineering questions at this nexus, but to train the next generation of researchers in this interdisciplinary area.

NSF In Action

In arid New Mexico, NSF EPSCoR researchers are modelling different scenarios to demonstrate the impact that water pricing, population growth, education, and drought have on the groundwater aquifer for the Albuquerque, Santa Fe, and Rio Rancho areas. They showed that price incentives impact indoor and outdoor water use and lower water use by more than 15 percent per capita. Their research also indicated that as more droughts occur in tandem with population increases, the aquifer has a lower chance of recovery. Such findings can assist city planners, officials, and citizens with plans to slow aquifer depletion.

This activity is an example of the type of water research that INFEWS will build upon to address the larger food-energy-water nexus.

NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science), is an integrated, national initiative to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or under-represented in the science, technology, engineering, and mathematics (STEM) enterprise. In FY 2017, NSF investment in this key priority is $16.0 million. Building on activities underway in FY 2015 and FY 2016, NSF will proceed to full implementation of NSF INCLUDES in FY 2017. Investments aim to produce, through alliances organized within a national network, rapid progress on changing the balance of diversity in science and engineering, have significant national impact for the participation of underrepresented groups, stimulate the community, forge new partnerships, and catalyze new approaches. NSF INCLUDES will build on and amplify other NSF investments in broadening participation.

NSF in Action

One groundbreaking NSF-supported project introduces girls from under-resourced areas to the emerging field of co-robotics. The girls, aged 8 to 12, learn to program co-robots — humanoid bots that work collaboratively with people. The girls tackle problems such as how robots should interact with people and how they might express emotion. The project expands the NSF-funded COMPUGIRLS, which was founded by social scientist and White House Champion of Change Kimberly Scott. COMPUGIRLS offers informal-learning programs in which girls explore the latest technologies in digital media, game development, and virtual worlds. Girls should know they belong in computer science, said Marquette University's Andrew Williams, who conceived of "Co-Robots for COMPUGIRLS." "They can have a vision of computer science or robotics and can someday apply it at a place like Google."

FY 2017 Ongoing NSF-Wide Priorities

NSF invests in a number of ongoing Foundation-wide programs that focus on addressing the most pressing challenges that face our Nation today. Foundation-wide programs and priorities bring together researchers from all fields of science and engineering to work on projects no one field can address on its own. These interdisciplinary investments are carefully balanced with a longstanding commitment to the fundamental research that addresses grand challenges and furthers basic scientific knowledge.

FY 2017 Funding for Ongoing NSF-Wide Investments

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	Percent
Cyber-Enabled Materials, Manufacturing and Smart Systems (CEMMSS)	$269.83	$256.30	$257.12	$0.82	0.3%
Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21)	157.04	132.42	100.07	-32.35	-24.4%
NSF Innovation Corps (I-Corps™)	26.19	30.00	30.00	-	-
Research at the Interface of Biological, Mathematical, and Physical Sciences (BioMaPS)	35.47	31.31	29.81	-1.50	-4.8%
Science, Engineering, and Education for Sustainability (SEES)	183.01	74.73	52.48	-22.25	-29.8%
Secure and Trustworthy Cyberspace (SaTC)	124.71	129.75	149.75	20.00	15.4%

- **Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS)** ($257.12 million) aims to integrate a number of science and engineering activities across the Foundation – breakthrough materials, advanced manufacturing, and smart systems, which includes robotic, cyber-physical, and autonomous systems. It will address pressing technological challenges facing the Nation and promote U.S. economic competitiveness in a variety of sectors. In FY 2017, CEMMSS continues to leverage key interagency activities, including the Administration's Materials Genome Initiative, Advanced Manufacturing Partnership, and the National Robotics Initiative. Through CEMMSS, NSF also invests in Advanced Manufacturing ($175.74 million) to advance cutting-edge manufacturing, as described in the *National Strategic Plan for Advanced Manufacturing.*

- **Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21)** ($100.07 million) accelerates and transforms the process of scientific discovery and innovation by providing advanced cyberinfrastructure that enables new functional capabilities in computational and data-enabled science and engineering across all disciplines. CIF21 has a planned sunset at the end of FY 2017, but efforts will inform a subsequent, focused set of activities for FY 2018 as a part of the Administration's new National Strategic Computing Initiative (NSCI).

- **NSF Innovation Corps (I-Corps™)** ($30.0 million) improves NSF-funded researchers' access to resources that can assist in bridging the gap between discoveries and speed knowledge transfer to downstream technological applications and use at scale. In FY 2017, NSF will continue to support I-Corps™ Nodes and I-Corps™ Sites to further build, utilize, and sustain a national innovation ecosystem that helps researchers effectively identify viable market opportunities and augments the development of technologies, products, and processes that benefit the Nation.

- **Research at the Interface of Biological, Mathematical, and Physical Sciences (BioMaPS)** ($29.81 million) involves the Directorates for Biological Sciences and Mathematical and Physical Sciences, and it seeks to advance discovery at the intersections of these established disciplines. Research includes activities such as development of models, informed by statistical physics that establish the mechanisms linking the biological function of chromosomes to their cellular structure.

- **Science, Engineering, and Education for Sustainability (SEES)** ($52.48 million) supports investments to increase understanding of the integrated system of supply chains, society, the natural world, and alterations humans bring to Earth, in order to create a sustainable world. FY 2017 is the last year in which funding will be formally associated with the SEES portfolio; however, through the planned sunsetting, SEES continues to support important scientific contributions and will make significant progress towards achieving programmatic goals through projects currently underway. Several SEES components with significant community interest will be continued through core programs and other aspects will be folded into the INFEWS and Risk and Resilience investments.

- The **Secure and Trustworthy Cyberspace (SaTC)** ($149.75 million) investment aims to build the knowledge base in cybersecurity that enables discovery, learning and innovation, and leads to a more secure and trustworthy cyberspace. Through a focus on long-term, foundational research, SaTC will develop the scientific foundations for cybersecurity research for years to come. SaTC also focuses on the training of the next generation cybersecurity workforce, especially for government. SaTC aligns NSF's cybersecurity investments with the national cybersecurity strategy.

Additional Highlights

NSF continues to emphasize investments in important or emerging areas that have been developed in recent years, including:

- NSF aims to increase the operational efficiency of **U.S. activities in the Antarctic** ($23.50 million) by continuing progress on a multi-year commitment toward more efficient and cost-effective science support as recommended by the U.S. Antarctic Program Blue Ribbon Panel report, *More and Better Science in Antarctica through Increased Logistical Effectiveness*. Emphases include investing in cargo-carrying capabilities for the South Pole heavy traverse, adding to its ability to deliver fuel, as well as continued investment in vehicle fleet and lifecycle capital equipment purchases to modernize Antarctic inventories and ensure facilities efficiency. This includes targeted investment in information technology infrastructure upgrades such as network management hardware, as well as design work for a new satellite earth station to move the primary communications facility from Black Island to McMurdo Station. Included in the total investment for FY 2017 is $5.0 million for the Antarctic Infrastructure Modernization for Science (AIMS) preconstruction planning project.

- In FY 2017, support for several of NSF's **astronomy and astrophysics** facilities investments reaches a decision point. A 2012 portfolio review was conducted under the auspices of the Advisory Committee for the Directorate for Mathematical and Physical Sciences in order to align budget realities with the 2010 National Research Council decadal survey, "*New Worlds, New Horizons in Astronomy and Astrophysics.*" Based on these recommendations, NSF is developing potential divestment options for several facilities.

- As the CIF21 investment sunsets in FY 2017, NSF will develop a subsequent, focused set of activities aligned with the Administration's new **National Strategic Computing Initiative (NSCI)** ($33.20

million) in order to focus efforts on advancing the Nation's computational infrastructure for science and engineering research. The rich topic of data, encompassing data science, data assimilation, data management, data policy, community building, and workforce development, will remain a strategic focus under the new NSF Data for Scientific Discovery and Action (D4SDA) activity, which will span research and research infrastructure.

Education and STEM Workforce

NSF's education and STEM workforce investment, centered in the Directorate for Education and Human Resources (EHR), funds activities that support students, teachers, researchers, and the public. The EHR investment in core STEM education research is critical to building the Nation's knowledge base for improving STEM learning. In keeping with the Administration's priorities and the strategic goals for STEM education as described in the Federal STEM Education Strategic Plan,[1] NSF's investments for FY 2017 focus on the following priorities:

- The **CyberCorps®: Scholarship for Service (SFS)** program ($70.0 million) supports cybersecurity education and research at higher education institutions. SFS also focuses on workforce development by increasing the number of qualified students entering the fields of information assurance and cybersecurity, which enhances the capacity of the United States higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure. In FY 2017, $25.0 million of the total funding will lay the groundwork for SFS alumni to be available over the course of their careers to serve the federal government to help respond rapidly to cybersecurity challenges.

- **Computer Science for All (CS for All)** ($20.0 million) will build on ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation. Funds will support the development and assessment of prototype instructional materials, scalable and sustainable professional development models, approaches to preservice preparation for computer science teachers, and teacher resources. CS for All will also fund research that will add to knowledge of effective approaches to the teaching and learning of computer science across grades K-12.

- The **Improving Undergraduate STEM Education (IUSE)** ($109.0 million) initiative supports the development of the STEM and STEM-capable workforce by investing in the improvement of undergraduate STEM education, with focus both on attracting and retaining students, and on degree completion..

- Through the **Advanced Technological Education (ATE)** ($66.00 million) program, NSF is able to reach technicians in undergraduate programs preparing for the high-technology fields that drive our Nation's economy. The ATE program is actively engaged in connecting community college educators funded by the program to the Institutes for Manufacturing Innovation within the National Network for Manufacturing Innovation.

- The **Graduate Research Fellowship (GRF)** ($332.16 million) program recognizes students with high potential in STEM research and innovation and provides support for them to pursue multidisciplinary research. GRF fellows may participate in Graduate Research Opportunities Worldwide (GROW), which provides opportunities to conduct research with international partner countries and organizations, and Graduate Research Internship Program (GRIP), which provides professional development through research internships at federal agencies. An NSF-wide strategic plan for investment in graduate education will be released in FY 2016.

[1] National Science and Technology Council. Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

- **The NSF Research Traineeship (NRT)** ($58.63 million) program invests directly in the development of the STEM workforce, and in the improvement of the education of tomorrow's STEM workforce. NRT funds proposals to test, develop, and implement innovative and effective STEM graduate education models, to promote interdisciplinary and broad professional training of graduate students, and to foster fundamental research advances in support of national priorities. NRT thus provides a mechanism for developing a knowledge base about the implementation and impact of innovative graduate traineeship programs and graduate education policies.

Major Research Equipment and Facilities Construction

In FY 2017, NSF requests funding to begin construction of one new project, the Regional Class Research Vessel (RCRV), and to continue construction of two projects, the Daniel K. Inouye Solar Telescope (DKIST) and the Large Synoptic Survey Telescope (LSST).

- The **Regional Class Research Vessel** (RCRV) ($106.0 million) project will initiate construction of two ships to meet anticipated ocean science requirements for the U.S. East Coast, West Coast, and Gulf of Mexico consistent with the recent report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*.[2] The RCRV project is a major component in the plan for modernizing the U.S. Academic Research Fleet (ARF).[3]

- The **Daniel K. Inouye Solar Telescope** ($20.0 million) will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromosphere, and corona at unprecedented spatial, temporal, and wavelength resolution to gain information on the creation, interaction, and ultimate annihilation of solar magnetic fields. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and coronal mass ejections. These can affect civil life on Earth through the phenomena generally described as "space weather" and may have impact on the terrestrial climate. FY 2017 is year nine of an eleven year construction process. In FY 2017, the Coudé rotator platform will be commissioned and accepted. The installation of the Telescope Mount Assembly (TMA) electrical systems will be completed, and commissioning and acceptance testing of the TMA will begin. The Coudé lab room will be complete and various components of the Coudé optics system installed. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered, assembled and will begin initial checkout.

- The **Large Synoptic Survey Telescope** ($67.12 million) will be an 8-meter-class wide-field optical telescope designed to carry out surveys of the entire sky available from its site. LSST will collect nearly 40 terabytes of multi-color imaging data every night and will produce the deepest, widest-field sky image ever. It will image the entire visible sky twice per week, as well as issue alerts for moving and transient objects within 60 seconds of their discovery. The LSST surveys will result in a comprehensive data set that will enable hundreds of other fundamental astrophysical studies by the entire research community. FY 2017 is year four of a nine year construction process. In FY 2017, work on the summit facility will be completed with the installation of the dome. The telescope structure will be factory tested and shipped to the site for installation. Integration of the innovative primary-tertiary mirror into its support cell will begin, and polishing of the secondary mirror will be finished. The camera cryostat will be made, the first sensor raft will be completed, and the camera's active support structure will be delivered. The data management project expects to deliver its initial archive and finalize the interface to the dedicated education and public outreach system.

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[2] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences
[3] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013
www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

Major Research Equipment and Facilities Construction Funding

(Dollars in Millions)

	FY 2015 Enacted	FY 2016 Estimate	FY 2017 Request
Ongoing Projects:			
Daniel K. Inouye Solar Telescope (DKIST)	$25.12	$20.00	$20.00
Large Synoptic Survey Telescope (LSST)	79.64	99.67	67.12
National Ecological Observatory Network (NEON)	96.00	80.64	-
Regional Class Research Vessel (RCRV)	-	-	106.00
Total, MREFC	**$200.76**	**$200.31**	**$193.12**

Totals may not add due to rounding.

Organizational Excellence

NSF seeks to integrate mission, vision, and core values to efficiently and effectively execute our activities and provide the flexibility and agility required for all aspects of its operations. This goal incorporates a culture of continuous improvement to ensure effective, inclusive, and accountable programs and merit review processes that provide the greatest value for taxpayer dollars.

Staffing

In FY 2017, NSF will work towards full utilization of its established FTE allocations, which are consistent with the FY 2016 Estimate of 1,442. The Foundation recognizes that maintaining staffing levels is vital for managing increasing numbers of proposals and the subsequent increase in workload.

FY 2017 Priorities

In FY 2017, the primary drivers of the increase for the Agency Operations and Award Management (AOAM) account are the headquarters relocation, the 1.6 percent cost-of-living adjustment and related salary and benefit increases, and information technology investments supporting DATA Act requirements, implementation of electronic invoicing, system updates, and increased security. AOAM also supports operational activities to ensure the Foundation has sufficient resources to fully fund ongoing operational requirements and maintain essential services as we approach the transition to the new NSF headquarters. These include strengthening capabilities in administrative services and human resource management.

Organizational Excellence by Appropriation

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Agency Operations & Award Management (AOAM)	$306.56	$330.00	$373.02	$43.02	13.0%
National Science Board (NSB)	4.15	4.37	4.38	0.01	0.2%
Office of Inspector General (OIG)	14.60	15.16	15.20	0.04	0.3%
Program Support:					
Research and Related Activities	107.30	110.74	128.75	18.01	16.3%
Education and Human Resources	16.21	17.28	20.18	2.90	16.8%
Subtotal, Program Support	*$123.52*	*$128.01*	*$148.94*	*$20.93*	*16.4%*
Total	**$448.83**	**$477.54**	**$541.53**	**$63.99**	**13.4%**

Total may not add due to rounding.

2014-2018 Strategic Plan and Performance

2014-2018 Strategic Plan
Integral to this submission is the NSF Strategic Plan for 2014-2018: *Investing in Science, Engineering, and Education for the Nation's Future*. The goals and strategies outlined in the plan build on lessons learned from NSF's past successes and continue to uphold NSF's mission: "To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense...."

The plan presents the following goals, which guide the FY 2017 Budget Request:

- "Transform the Frontiers of Science and Engineering" aims to expand and explore the frontiers of human knowledge to enhance the power of the Nation to meet its challenges, and to create new paradigms and capabilities for scientific, technological, and economic leadership in an increasingly fast-paced, competitive world.

- "Stimulate Innovation and Address Societal Needs through Research and Education" strives to focus NSF's research communities on opening up new avenues to address high priority national challenges, as well as encourages formation of partnerships with industry, other agencies, and international counterparts to leverage resources and build capacity.

- "Excel as a Federal Science Agency" focuses on efficiently and effectively executing the agency's responsibilities and achieving the flexibility and agility required to meet the quickly evolving challenges associated with the first two strategic goals.

This goal structure enables NSF to link its investments to longer-term outcomes. To bridge the gap between these strategic goals and measurable outputs, the Strategic Plan establishes a set of strategic objectives for each strategic goal.

Performance Plan
NSF embraces the use of goals to drive performance improvements. For FY 2017, NSF has set nine performance goals so that NSF can strategically monitor and oversee progress being made towards its larger aims. NSF also assesses progress through an annual process of strategic reviews of the objectives in its Strategic Plan.

In FY 2017, NSF will monitor the following annual goals:

- **Agency Priority Goal – Improve Graduate Student Preparedness:** Improve STEM graduate student preparedness for entering the workforce.

- **Agency Priority Goal – Invest Strategically in Public Participation in STEM Research (PPSR):** Build the capacity of the Nation to solve research challenges and improve learning by investing strategically in crowdsourcing and other forms of public participation in science, technology, engineering, and mathematics (STEM) research.

- **Ensure that Key Program Investments are on Track:** NSF will monitor progress on four investments using a set of common milestones and indicators: 1) Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES), 2) Innovations at the Nexus of Food, Energy, Water, and Social Systems (INFEWS), 3) Risk and Resilience, and 4) Understanding the Brain (UtB).

- **Ensure that Infrastructure Investments are on Track:** Ensure program integrity and responsible stewardship of major research facilities at varying stages of their lifecycle. In FY 2017, this involves monitoring the performance of construction projects.

- **Use Evidence to Guide Decisions:** NSF will use evidence-based reviews to guide management investments.

- **Make Timely Award Decisions:** NSF aims to inform applicants whether their proposals have been declined or recommended for funding within 182 days, or six months of deadline, target, or receipt date, whichever is later.

- **Foster a Culture of Inclusion:** NSF seeks to foster a culture of inclusion through change management efforts resulting in change leadership and accountability.

- **Evaluate NSF Investments:** Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.

- **Increase the Percentage of Panelists Participating in Merit Review Virtually:** Increase the percentage of proposal review panelists that participate virtually while maintaining the quality of the merit review process.

Please refer to performance.gov for information on NSF's Agency Priority Goals and NSF's contributions to the federal Cross-Agency Priority (CAP) goals.

Cuts, Consolidations, Savings, and Lower Priority Programs

NSF's FY 2017 Request follows a thorough examination of programs and investments across NSF to determine where the potential exists for more innovative investments. This Request includes two proposed terminations, one reduction, and two administrative savings, totaling $46.10 million.

Enhancing Access to the Radio Spectrum (EARS) (-$16.0 million) is a cross-cutting program initiated in FY 2012 whose purpose was to fund interdisciplinary research that enhances the efficiency with which radio spectrum is used and/or leads to greater access to wireless services for all Americans. EARS was a partnership of the Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), Mathematical and Physical Science (MPS), and Social, Behavioral, and Economic Sciences (SBE) to support research in new wireless communications and spectrum sharing architectures and services. In FY 2017, CISE, ENG, and MPS will terminate investment in EARS, but will continue ongoing support of research for wireless communication, spectrum sharing, and mobile computing as well as the development of wireless and spectrum testbeds. SBE's support concluded in FY 2014.

Integrated NSF Support Promoting Interdisciplinary Research & Education (INSPIRE) (-$25.35 million) was established to address the myriad scientific challenges that lie at the intersections of traditional disciplines. It was aimed at strengthening NSF's support of interdisciplinary, potentially transformative research within the directorates by complementing existing efforts with a suite of innovative Foundation-wide activities and funding opportunities. Based on initial analysis of the INSPIRE portfolio, NSF has determined that dedicated funding is not necessary to encourage the kinds of projects supported through INSPIRE. Starting in FY 2017, each directorate will continue support for INSPIRE-like interdisciplinary research through core and cross-cutting programs, coordinating with other directorates and divisions, as necessary, for internal review of these projects. NSF anticipates developing a new funding mechanism that will manifest many of the principles of INSPIRE.

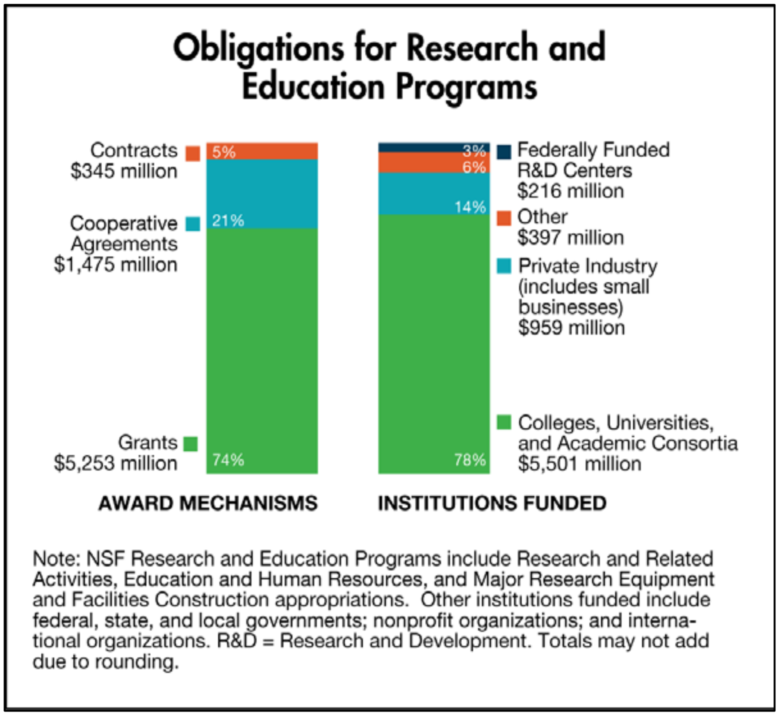
National Solar Observatory (NSO) (-$3.50 million) is reduced as part of the planned transition away from existing NSO facilities (NSO Integrated Synoptic Program, Dunn Solar Telescope, and McMath-Pierce Solar Telescope) and toward the Daniel K. Inouye Solar Telescope (DKIST).

Strategic Human Capital Support Contracts (-$810,000) funding is decreased due to NSF's planned investment in business intelligence and other tools, supported in the FY 2016 Request, which are anticipated to reduce the cost of contract support.

Information Dissemination (-$440,000) costs associated with maintenance and support of the NSF website are decreased due to a recent retirement of dated infrastructure and the conversion of content to modern platforms.

NSF by the Numbers

NSF by The Numbers: In FY 2017, NSF expects to evaluate over 52,000 proposals through a competitive merit review process and make over 12,000 new awards. This will require over 230,000 proposal reviews, engaging on the order of 35,000 members of the science and engineering community participating as panelists and proposal reviewers. In a given year, NSF awards reach over 1,800 colleges, universities, and other public and private institutions in 50 states, the District of Columbia, and Puerto Rico. In FY 2017, NSF support is expected to reach approximately 377,000 researchers, postdoctoral fellows, trainees, teachers, and students.



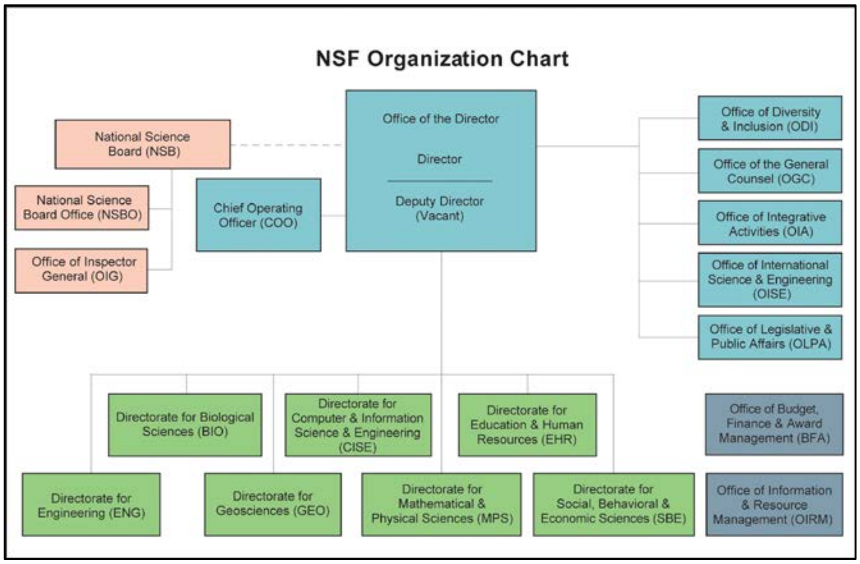
The chart on the right shows the distribution of NSF's obligations by institution type and funding mechanism. While the data are based on FY 2015, the relative shares should provide a good indication of the FY 2017 distribution. As shown on the graph, 95 percent of NSF's FY 2015 projects were funded using grants or cooperative agreements. Grants can be funded either as standard awards, in which funding for the full duration of the project is provided in a single fiscal year, or as continuing awards, in which funding for a multi-year project is provided in increments. Cooperative agreements are used when the project requires substantial agency involvement during the project performance period (e.g., research centers, multi-user facilities.). Contracts are used to acquire products, services, and studies (e.g., program evaluations) required primarily for NSF or other government use.

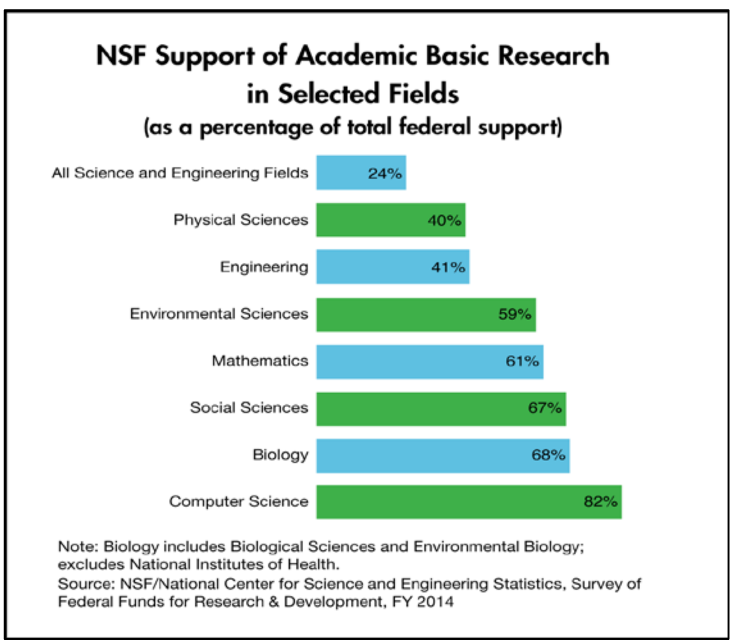
Most NSF awards are to academic institutions. As shown in the chart, 78 percent of support for research and education programs ($5,501 million) was to colleges, universities, and academic consortia. Private industry, including small businesses, accounted for 14 percent ($959 million), and support to Federally Funded Research and Development Centers (FFRDCs) accounted for 3 percent ($216 million). Other recipients included federal, state, and local governments; nonprofit organizations; and international organizations. A small number of awards fund research in collaboration with other countries, which adds value to the U.S. scientific enterprise and maintains U.S. leadership in the global scientific enterprise.

Organization and Role in the Federal Research Enterprise

NSF's comprehensive and flexible support of meritorious projects enables the Foundation to identify and foster both fundamental and transformative discoveries and broader impacts within and among fields of inquiry. NSF has the latitude to support emerging fields, high-risk ideas, interdisciplinary collaborations, and research that pushes – and even creates – the very frontiers of knowledge. In these ways, NSF's discoveries inspire the American public – and the world.

NSF's organization represents the major science and engineering fields, including: biological sciences; computer and information science and engineering; engineering; geosciences; mathematical and physical sciences; and social, behavioral, and economic sciences. NSF also carries out specific responsibilities for education and human resources, integrative activities, and international science and engineering. The 25-member National Science Board sets the overall policies of the Foundation.





NSF's annual budget represents 24 percent of the total federal budget for basic research conducted at U.S. colleges and universities, and this share increases to nearly 60 percent when medical research supported by the National Institutes of Health is excluded. In many science and engineering fields NSF is the primary source of federal academic support.

Highlights

For over 60 years, NSF has pursued investments in fundamental research and education to fulfill its mission of promoting the progress of science and engineering. In doing so, NSF-supported research has connected the discovery and advancement of knowledge with the potential societal, economic, and educational benefits that are critical for continued U.S. prosperity. Below are just a few of the important recent advances that NSF funding continues to enable.

Supercomputer Cybersecurity

The Bro Network Security Monitor protects many scientific computing networks.

Credit: Bro Center of Expertise

Computer networks at national labs, scientific computing facilities, universities, and large companies identify and block hundreds of thousands of hostile intrusions every month, thanks to a freely available cybersecurity software advanced by NSF-funded computer scientists at the University of California, Berkeley. The programmable "Bro" code analyzes a network's unique data traffic patterns and tailors its defenses as needed, depending on the anomalies detected. The code played a critical role in identifying hackers trying to sell access to federal supercomputers. The NSF-funded Bro Center of Expertise provides resources for users to protect their cyberinfrastructure.

Hunting for Gravitational Waves

NSF, in May 2015, helped dedicate the Advanced Laser Interferometer Gravitational-Wave Observatories (LIGO) in Washington State. Researchers using the facilities seek to observe and record gravitational waves for the first time. Those discoveries would allow us to learn more about the phenomena that generate the waves, such as supernovae and colliding black holes. The Advanced LIGO project represents a major upgrade expected to enhance the sensitivity of LIGO's instruments by a factor of at least 10 and can see a volume of space more than 1,000 times greater than the initial LIGO. The existence of gravitational waves is a crucial prediction of the General Theory of Relativity.

Image of the LIGO observatory in Hanford, Washington, where astronomers completed a major upgrade in a quest to understand the extraordinary mysteries of our universe.

Credit: *Cfoellmi via Wikimedia Commons*.

Highlights

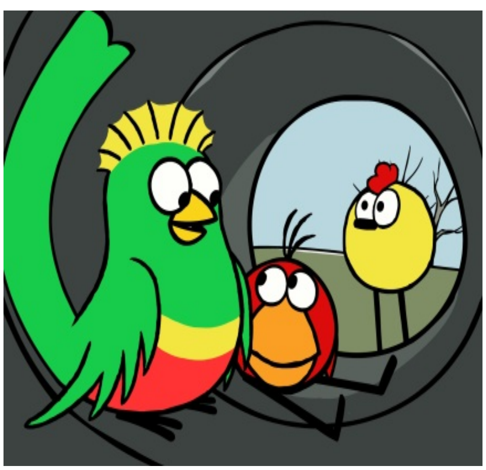
Researchers Look to Fill a Critical Cybersecurity Gap

Cybersecurity experts have for years called the insider threat – someone within an institution or agency who can, intentionally or not, gain access to a system and create dangerous vulnerabilities – one of the most serious problems in the digital world. To address that challenge, researchers at the University of Texas at Arlington and the State University of New York at Buffalo are working with a major financial institution to study the insider threat. By studying behavior logs for that institution's computer networks, the research team has been able to assess risk levels for different types of information and identify potential vulnerabilities that cyberattackers could exploit. The research, designed to help build future network access controls, is one of a group of NSF-funded projects focusing on solving cybersecurity problems with behavioral science.

Researchers partnered with a financial institution to obtain anonymized access records for every interaction with their computer networks by several thousand internal users

Credit: © iStock.com/KevinAlexanderGeorge

PBS Series Engages Latino Children in Math and Science



Animation still from *Peep and the Big Wide World*

Credit: WGBH Education Foundation

Peep and the Big Wide World, an NSF-funded Emmy award-winning Public Broadcasting Service series, developed an outreach campaign to encourage greater family involvement, particularly among Latino families, in children's exploration of math and science. A Spanish-speaking character, "Splendid Bird from Paradise," was added to the animated cast, and parents, including Spanish speakers, are now featured in the live-action videos. A multipronged study found that Spanish-speaking parents who used Peep resources with their preschool-age children were better equipped to facilitate science and math exploration. The parents reported feeling more inclined to do math and science activities with their preschoolers and said the resources are easy to understand, fun, and help them learn science alongside their children.

Highlights

Control of Soot Formation in Flames

Environmental soot, which is associated with respiratory illness and cancer, is a deadly pollutant and a leading man-made contributor to global warming. A ternary flame system developed to study soot oxidation could save thousands of lives and contribute to a cleaner environment. This novel flame system, developed by NSF-funded researchers at the University of Maryland, College Park, allows complicated flame processes to be separated and controlled. In ordinary flames, soot formation and oxidation regions overlap, preventing either process from being studied independently. The ternary system will allow soot oxidation to be studied in a region without soot formation, which could lead to more accurate computer models used in the design of engines and other combustors.

Soot oxidation will be studied in the yellow flame at the top of the ternary flame system seen in this image.

Credit: Haiqing Guo and Peter B. Sunderland, University of Maryland, College Park

Cosmic Confirmation

Photo of IceCube, a neutrino observatory whose detectors are buried more than 1 mile below the surface of the South Pole.

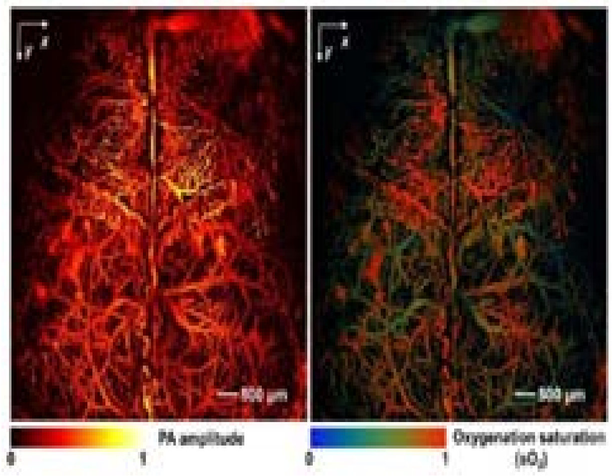
Credit: Emanuel Jacobi, National Science Foundation

Researchers using a massive, NSF-funded instrument buried deep in the ice at the South Pole observed high-energy neutrinos from beyond our solar system—and beyond our galaxy. Billions of the subatomic particles known as neutrinos pass through Earth every day but are difficult to detect. The IceCube Neutrino Observatory, a cubic-kilometer-sized detector sunk into the South Pole ice sheet, allows researchers to see byproducts of neutrino interaction with ice. A 2015 observation confirmed the discovery of high-energy neutrinos IceCube made in 2013. "Cosmic neutrinos are the key to yet unexplored parts of our universe and might be able to finally reveal the origins of the highest energy cosmic rays, including the rare 'Oh-My-God' particles," said IceCube Collaboration spokesperson Olga Botner.

Highlights

Imaging the Brain in Real Time

Overcoming the light-scattering effects of tissue, NSF-funded researchers at Washington University in St. Louis (WUSTL) use laser light to peer into the brain to unprecedented depths (nearly 3 inches). The approach they pioneered, termed photoacoustic imaging, combines laser light and sound waves. The technique allows the study of biological material, from cells to tissues and organs, in its natural environment, free of imaging agents. It detects single red blood cells as well as fats and proteins. The researchers are integrating the technique into a system to capture images every 1/1,000th of a second—fast enough to image action potentials (changes in electrical potential along a nerve fiber when a nerve impulse is transmitted.



The mouse brain was visualized using label-free photoacoustic microscopy.

Credit: Junjie Yao and Lihong Wang, WUSTL

Energy Savings through Wind Power

This image shows turbines on the Cedar Creek wind farm with plowed fields beneath.

Credit: © University Corporation for Atmospheric Research

Xcel Energy, the leading wind energy producer in the U.S., relies on a highly detailed wind forecasting system developed through a partnership with the NSF-funded National Center for Atmospheric Research (NCAR). Since 2009, the forecasting system has saved Xcel customers about $49 million. Accurate predictions of wind timing and intensity at turbine sites allow the company to decide when to switch from costly coal and natural gas to wind power to generate electricity. Global Weather Corporation (GWC), an NCAR spinoff company, now markets the forecasting system along with several other forecast modeling technologies. GWC forecasts have a 99.9 percent accuracy.

SUMMARY TABLES

Total NSF Funding:

Major NSF-wide Investments:

STEM Education and Workforce:

Research Infrastructure:

National Science Foundation
Summary Tables
FY 2017 Budget Request to Congress
(Dollars in Millions)

NSF by Account	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request Discretionary over FY 2016 Estimate: Amount	FY 2017 Request Discretionary over FY 2016 Estimate: Percent	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request change over FY 2016 Estimate: Amount	FY 2017 Request change over FY 2016 Estimate: Percent
BIO	$736.19	$744.17	$745.73	$1.56	0.2%	$44.79	$790.52	$46.35	6.2%
CISE	932.98	935.82	938.43	2.61	0.3%	56.37	994.80	58.98	6.3%
ENG	923.53	916.19	946.41	30.22	3.3%	56.32	1,002.73	86.54	9.4%
Eng Programs	*746.42*	*727.63*	*744.74*	*17.11*	*2.4%*	*44.73*	*789.47*	*61.84*	*8.5%*
SBIR/STTR	*177.11*	*188.56*	*201.67*	*13.11*	*7.0%*	*11.59*	*213.26*	*24.70*	*13.1%*
GEO	1,319.04	1,318.54	1,319.56	1.02	0.1%	79.27	1,398.83	80.30	6.1%
MPS	1,376.32	1,349.15	1,355.06	5.91	0.4%	81.39	1,436.45	87.30	6.5%
SBE	276.19	272.20	272.41	0.21	0.1%	16.36	288.77	16.57	6.1%
OISE	48.46	49.10	49.10	-	-	2.95	52.05	2.95	6.0%
IA	427.46	447.06	451.30	4.24	0.9%	8.56	459.86	12.80	2.9%
U.S. Arctic Research Commission	1.41	1.43	1.43	-	-	-	1.43	-	-
Research & Related Activities	**$6,041.57**	**$6,033.65**	**$6,079.43**	**$45.78**	**0.8%**	**$346.01**	**$6,425.44**	**$391.79**	**6.5%**
Education & Human Resources	**$886.33**	**$880.00**	**$898.87**	**$18.87**	**2.1%**	**$53.99**	**$952.86**	**$72.86**	**8.3%**
Major Research Equipment & Facilities Construction	**$144.76**	**$200.31**	**$193.12**	**-$7.19**	**-3.6%**	**-**	**$193.12**	**-$7.19**	**-3.6%**
Agency Operations & Award Management	**$306.56**	**$330.00**	**$373.02**	**$43.02**	**13.0%**	**-**	**$373.02**	**$43.02**	**13.0%**
National Science Board	**$4.15**	**$4.37**	**$4.38**	**$0.01**	**0.2%**	**-**	**$4.38**	**$0.01**	**0.2%**
Office of Inspector General	**$14.60**	**$15.16**	**$15.20**	**$0.04**	**0.3%**	**-**	**$15.20**	**$0.04**	**0.3%**
Total, NSF	**$7,397.97**	**$7,463.49**	**$7,564.02**	**$100.53**	**1.3%**	**$400.00**	**$7,964.02**	**$500.53**	**6.7%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1-B Non-Immigrant Petitioner mandatory funds.

NSF Funding Profile

The Funding Profile presents a high level, agency-wide estimate of proposal pressure, funding rates (or proposal "success"), and award statistics. These indicators are useful in gauging the relative impact of different funding levels.

Statistics for Competitive Awards: Competitive awards encompass the universe of NSF new activity in a given year. Examples include research grants, cooperative agreements, equipment, fellowships, and conferences.

Statistics for Research Grant Awards: Research Grant Awards are a sub-set of competitive awards. They are limited to research projects and exclude other categories of awards such as those for cooperative agreements, equipment, fellowships, and conferences.

The Number of Proposals is based on several factors, including past actual activity, planned competitions, and research trends within the various disciplinary communities. External factors, such as the state of the national economy and other sources of funding, also play a part. The Number of Awards is also based on several factors, including estimated funding and expected proposal pool. The Funding Rate is the number of awards made during a year as a percentage of total proposals competitively reviewed. This indicates the probability of receiving an award when submitting proposals to NSF. Annualized Award Size shows the annual level of research grant awards provided to awardees by dividing the total dollars of each award by the number of years over which it extends. Average Duration is the length of awards in years.

NSF Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Discretionary Estimate	FY 2017 Request Estimate
Statistics for Competitive Awards				
Number of Proposals	49,600	50,800	52,200	54,100
Number of Awards	12,000	12,100	12,200	13,100
Funding Rate	24%	24%	24%	24%
Statistics for Research Grant Awards				
Number of Research Grant Proposals	40,900	42,200	43,200	45,000
Number of Research Grant Awards	9,000	9,200	9,300	10,100
Funding Rate	22%	22%	22%	23%
Median Annualized Award Size	$137,300	$140,100	$140,200	$146,400
Average Annualized Award Size	$173,200	$176,700	$178,200	$179,000
Average Duration (years)	2.9	3.0	3.0	3.0

Number of People Involved in NSF Activities

NSF estimates that in FY 2017 approximately 377,170 people will be directly involved in NSF programs and activities, receiving salaries, stipends, participant support, and other types of direct involvement. Beyond these figures, NSF programs indirectly impact millions of people, reaching K-12 students and teachers, the general public, and researchers through activities including workshops; informal science activities such as museums, television, videos, and journals; outreach efforts; and dissemination of improved curriculum and teaching methods.

FY 2017 Request
Number of People Involved in NSF Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Discretionary Estimate	FY 2017 Request Estimate
Senior Researchers	42,241	42,690	42,980	45,520
Other Professionals	13,990	13,960	14,145	14,970
Postdoctoral Associates	6,043	6,060	6,180	6,470
Graduate Students	42,114	41,870	42,370	45,080
Undergraduate Students	35,785	35,530	36,075	38,030
K-12 Teachers	41,330	40,900	42,000	44,500
K-12 Students	173,128	169,000	172,800	182,600
Total Number of People	**354,631**	**350,010**	**356,550**	**377,170**

Senior Researchers include scientists, mathematicians, engineers, and educators receiving funding through NSF awards. These include both researchers who are principal or co-principal investigators on research and education projects, and researchers working at NSF-supported centers and facilities.

Other Professionals are individuals who may or may not hold a doctoral degree or its equivalent, are considered professionals but are not reported as senior researchers, postdoctoral associates, or students. Examples are technicians, systems experts, etc.

Postdoctoral Associates are individuals who have received Ph.D., M.D., D.Sc., or equivalent and are not faculty members of the performing institution. About 96 percent are supported through funds included in research projects, centers, or facilities awards. Others are recipients of postdoctoral fellowships.

Graduate Students include those compensated from NSF grant funds. Approximately 20 percent receive support through NSF's fellowship and traineeship programs. Others are supported through research assistantships and assist senior researchers or postdoctoral associates in performing research through awards for research projects, centers, or facilities. NSF provides support for approximately 30 percent of the U.S. science and engineering graduate students receiving federal funds and about five percent of the science and engineering graduate students in the U.S. overall.[1]

Undergraduate Students include students compensated from NSF grant funds who are enrolled in technical colleges or baccalaureate programs. They may be assisting senior researchers or postdoctoral

[1] Science and Engineering Indicators 2016: Chapter 2 Higher Education in Science and Engineering, Appendix Tables 02-07 and 02-11. www.nsf.gov/statistics/2016/nsb20161/#/data

associates in performing research, or participating in NSF programs aimed at undergraduate students, such as Research Experiences for Undergraduates.

K-12 Teachers include teachers at elementary, middle, and secondary schools. These individuals actively participate in intensive professional development experiences in the sciences and mathematics.

K-12 Students are those attending elementary, middle, and secondary schools. They are supported through program components that directly engage students in science and mathematics experiences.

NSF Budget Requests and Appropriations By Account: FY 2000 - FY 2017

(Millions of Current Dollars)

Click here for complete history

	Research & Related Activities (R&RA)		Education & Human Resources (EHR)		Major Research Equipment & Facilities Construction (MREFC)[1]		Agency Operations & Award Management (AOAM)[2]		Office of Inspector General (OIG)		National Science Board (NSB)		NSF, TOTAL	
Fiscal Year	Request	Appropriation	Request	Appropriation	Request	Appropriation	Request	Appropriation	Request	Appropriation	Request	Appropriation	Request	Appropriation
2000	3,004.00	2,972.90	678.00	690.87	85.00	93.50	149.00	149.28	5.45	5.45	-	-	3,921.45	3,912.00
2001	3,540.68	3,356.29	729.01	785.60	138.54	121.33	157.89	161.09	6.28	6.27	-	-	4,572.40	4,430.57
2002	3,326.98	3,612.26	872.41	894.28	96.33	138.80	170.04	171.26	6.76	6.75	-	-	4,472.52	4,823.35
2003	3,783.21	4,069.29	908.08	903.17	126.28	148.54	210.16	189.43	8.06	9.19	-	3.48	5,035.79	5,323.09
2004	4,106.36	4,262.12	938.04	938.98	202.33	154.98	225.70	218.96	8.77	9.94	-	3.88	5,481.20	5,588.86
2005	4,452.31	4,229.98	771.36	841.42	213.27	173.65	294.00	223.45	10.11	10.03	3.95	3.97	5,745.00	5,482.49
2006	4,333.49	4,339.21	737.00	796.69	250.01	190.88	269.00	247.06	11.50	11.35	4.00	3.95	5,605.00	5,589.14
2007	4,665.95	4,654.24	816.22	796.59	240.45	175.61	281.82	248.50	11.86	10.97	3.91	3.97	6,020.21	5,889.87
2008	5,131.69	4,841.73	750.60	765.60	244.74	220.74	285.59	281.79	12.35	11.43	4.03	3.97	6,429.00	6,125.26
2009	*5,593.99*	*5,186.17*	*790.41*	*845.26*	*147.51*	*152.01*	*305.06*	*294.15*	*13.10*	*12.00*	*4.03*	*4.03*	*6,854.10*	*6,493.61*
2009 ARRA	-	*2,500.00*	-	*100.00*	-	*400.00*		-	-	*2.00*		-	-	*3,002.00*
2009 Total	5,593.99	7,686.17	790.41	945.26	147.51	552.01	305.06	294.15	13.10	14.00	4.03	4.03	6,854.10	9,495.61
2010	5,733.24	5,563.92	857.76	872.76	117.29	117.29	318.37	300.00	14.00	14.00	4.34	4.54	7,045.00	6,872.51
2011	6,018.83	5,509.98	892.00	861.03	165.19	117.06	329.19	299.40	14.35	13.97	4.84	4.53	7,424.40	6,805.98
2012	6,253.54	5,689.00	911.20	829.00	224.68	197.06	357.74	299.40	15.00	14.20	4.84	4.44	7,767.00	7,033.10
2013	5,983.28	5,543.72	875.61	833.31	196.17	196.17	299.40	293.60	14.20	13.19	4.44	4.12	7,373.10	6,884.11
2014	6,212.29	5,808.92	880.29	846.50	210.12	200.00	304.29	298.00	14.32	14.20	4.47	4.30	7,625.78	7,171.92
2015	5,807.46	5,933.65	889.75	866.00	200.76	200.76	338.23	325.00	14.43	14.43	4.37	4.37	7,255.00	7,344.21
2016	6,186.30	6,033.65	962.57	880.00	200.31	200.31	354.84	330.00	15.16	15.16	4.37	4.37	7,723.55	7,463.49
2017 Discretionary	*6,079.43*	-	*898.87*	-	*193.12*	-	*373.02*	-	*15.20*	-	*4.38*	-	*7,564.02*	-
2017 Mandatory[3]	*346.01*	-	*53.99*	-	-	-	-	-	-	-		-	*400.00*	-
2017 Total	6,425.44	-	952.86	-	193.12	-	373.02	-	15.20	-	4.38	-	7,964.02	-

Totals may not add due to rounding.

[1]The Major Research Equipment and Facilities Construction (MREFC) account was previously known as Major Research Equipment (MRE) until FY 2002.

[2]The Agency Operations and Award Management (AOAM) account was known as Salaries & Expenses (S&E) until FY 2008.

[3] Includes only new mandatory funding. Excludes H1-B Non-Immigrant Petitioner mandatory funds.

National Science Foundation
Selected Crosscutting Programs
FY 2017 Budget Request to Congress
(Dollars in Millions)

Selected Cross-Cutting Programs		FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request	FY 2017 Request Change over FY 2016 Estimate: Amount	FY 2017 Request Change over FY 2016 Estimate: Percent
ADVANCE	Research & Related Activities	13.37	13.37	12.57	-	12.57	-0.80	-6.0%
	Education & Human Resources	1.52	1.53	1.53	-	1.53	-	-
	Total, NSF	**$14.89**	**$14.90**	**$14.10**	**-**	**$14.10**	**-$0.80**	**-5.4%**
Faculty Early Career Development - CAREER	Research & Related Activities	265.53	226.51	229.58	-	229.58	3.07	1.4%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$265.53**	**$226.51**	**$229.58**	**-**	**$229.58**	**$3.07**	**1.4%**
Graduate Research Fellowship - GRF	Research & Related Activities	166.72	165.96	166.08	-	166.08	0.12	0.1%
	Education & Human Resources	166.52	165.96	166.08	-	166.08	0.12	0.1%
	Total, NSF	**$333.24**	**$331.92**	**$332.16**	**-**	**$332.16**	**$0.24**	**0.1%**
NSF Research Traineeships - NRT[1]	Research & Related Activities	33.66	23.10	20.92	-	20.92	-2.18	-9.4%
	Education & Human Resources	40.74	31.05	37.71	-	37.71	6.66	21.4%
	Total, NSF	**$74.40**	**$54.15**	**$58.63**	**-**	**$58.63**	**$4.48**	**8.3%**
Total, Graduate Fellowships & Traineeships	Research & Related Activities	200.38	189.06	187.00	-	187.00	-2.06	-1.1%
	Education & Human Resources	207.26	197.01	203.79	-	203.79	6.78	3.4%
	Total, NSF	**$407.64**	**$386.07**	**$390.79**	**-**	**$390.79**	**$4.72**	**1.2%**
Integrated NSF Support Promoting Interdisciplinary Research and Education - INSPIRE	Research & Related Activities	21.57	25.35	-	-	-	-25.35	-100.0%
	Education & Human Resources	1.97	-	-	-	-	-	N/A
	Total, NSF	**$23.54**	**$25.35**	**-**	**-**	**-**	**-$25.35**	**-100.0%**
Long-Term Ecological Research Sites - LTERs	Research & Related Activities	26.09	27.95	27.95	1.00	28.95	1.00	3.6%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$26.09**	**$27.95**	**$27.95**	**$1.00**	**$28.95**	**$1.00**	**3.6%**
Research Experiences for Undergraduates - REU - Sites Only	Research & Related Activities	72.73	53.29	53.54	-	53.54	0.25	0.5%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$72.73**	**$53.29**	**$53.54**	**-**	**$53.54**	**$0.25**	**0.5%**
Research Experiences for Undergraduates - REU - Supplements Only	Research & Related Activities	24.10	22.14	22.04	-	22.04	-0.10	-0.5%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$24.10**	**$22.14**	**$22.04**	**-**	**$22.04**	**-$0.10**	**-0.5%**
Total, Research Experiences for Undergraduates - REU	Research & Related Activities	96.82	75.43	75.58	-	75.58	0.15	0.2%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$96.82**	**$75.43**	**$75.58**	**-**	**$75.58**	**$0.15**	**0.2%**
Research in Undergraduate Institutions - RUI	Research & Related Activities	35.35	39.15	40.15	-	40.15	1.00	2.6%
	Education & Human Resources	-	-	-	-	-	-	N/A
	Total, NSF	**$35.35**	**$39.15**	**$40.15**	**-**	**$40.15**	**$1.00**	**2.6%**

Totals may not add due to rounding.

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $12.97 million in FY 2015 and $6.35 million in FY 2016.

National Science Foundation
NSTC Crosscuts Summary
FY 2017 Request to Congress

(Dollars in Millions)

	National Nanotechnology Initiative (NNI)						
	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request change over FY 2016 Estimate Amount	Percent
BIO	$48.80	$48.80	$48.80	-	$48.80	-	-
CISE	13.75	13.75	13.75	-	13.75	-	-
ENG	219.95	168.50	168.50	-	168.50	-	-
GEO	0.30	0.30	0.30	-	0.30	-	-
MPS	203.07	180.62	180.37	-	180.37	-0.25	-0.1%
SBE	1.30	0.53	0.53	-	0.53	-	-
OISE	0.10	0.10	0.10	-	0.10	-	-
IA	-	-	-	-	-	-	N/A
R&RA	**$487.27**	**$412.60**	**$412.35**	**-**	**$412.35**	**-$0.25**	**-0.1%**
EHR	**$2.50**	**$2.50**	**$2.50**	**-**	**$2.50**	**-**	**-**
NSF Total	**$489.77**	**$415.10**	**$414.85**	**-**	**$414.85**	**-$0.25**	**-0.1%**

	Networking & Information Technology R&D (NITRD)						
	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request change over FY 2016 Estimate Amount	Percent
BIO	$99.00	$99.00	$99.00	-	$99.00	-	-
CISE	932.98	935.82	938.43	56.37	994.80	58.98	6.3%
ENG	28.97	29.30	29.80	-	29.80	0.50	1.7%
GEO	24.00	24.00	24.00	-	24.00	-	-
MPS	79.87	70.13	69.17	-	69.17	-0.96	-1.4%
SBE	30.97	28.14	28.14	-	28.14	-	-
OISE	-	-	-	-	-	-	N/A
IA	-	-	-	-	-	-	N/A
R&RA	**$1,195.79**	**$1,186.39**	**$1,188.54**	**$56.37**	**$1,244.91**	**$58.52**	**4.9%**
EHR	**$9.50**	**$9.50**	**$9.50**	**-**	**$9.50**	**-**	**-**
NSF Total	**$1,205.29**	**$1,195.89**	**$1,198.04**	**$56.37**	**$1,254.41**	**$58.52**	**4.9%**

	U.S. Global Change Research Program (USGCRP)						
	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request change over FY 2016 Estimate Amount	Percent
BIO	$66.00	$116.11	$125.00	-	$125.00	$8.89	7.7%
CISE	-	-	-	-	-	-	N/A
ENG	-	-	-	-	-	-	N/A
GEO	202.09	201.09	201.09	-	201.09	-	-
MPS	13.37	3.50	3.50	-	3.50	-	-
SBE	17.98	17.98	17.98	-	17.98	-	-
OISE	-	-	-	-	-	-	N/A
IA	-	-	-	-	-	-	N/A
R&RA	**$299.44**	**$338.68**	**$347.57**	**-**	**$347.57**	**$8.89**	**2.6%**
EHR	**-**	**-**	**-**	**-**	**-**	**-**	**N/A**
NSF Total	**$299.44**	**$338.68**	**$347.57**	**-**	**$347.57**	**$8.89**	**2.6%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1-B Non-Immigrant Petitioner mandatory funds.

National Science Foundation
Homeland Security Activities Summary
FY 2017 Request to Congress
(Dollars in Millions)

	BIO	CISE	ENG	GEO	MPS	SBE	IA	R&RA	EHR	AOAM	Total, NSF
FY 2015 Actual	**$15.00**	**$198.80**	**$148.61**	**$3.31**	**$7.05**	**$9.36**	**$2.56**	**$384.69**	**$45.42**	**$2.79**	**$432.90**
Protecting Critical Infrastructure & Key Assets	**-**	**$198.80**	**$148.61**	**$3.31**	**$7.05**	**$9.36**	**$2.56**	**$369.69**	**$45.42**	**$2.79**	**$417.90**
Antarctic Physical Security	-	-	-	0.30	-	-	-	$0.30	-	-	$0.30
Counterterrorism	-	27.00	-	-	-	-	-	$27.00	-	-	$27.00
Cybersecurity	-	147.00	5.11	-	1.11	5.32	-	$158.54	-	-	$158.54
Emergency Planning & Response	-	24.80	24.50	-	4.44	-	-	$53.74	-	-	$53.74
Energy Supply Assurance	-	-	26.00	-	-	-	-	$26.00	-	-	$26.00
IT Security	-	-	-	3.01	-	-	2.56	$5.57	0.38	2.79	$8.74
Resilient Infrastructure	-	-	93.00	-	1.50	4.04	-	$98.54	-	-	$98.54
Scholarship for Service/Cybercorps	-	-	-	-	-	-	-	-	45.04	-	$45.04
Defending Against Catastrophic Threats	**$15.00**	**-**	**-**	**-**	**-**	**-**	**-**	**$15.00**	**-**	**-**	**$15.00**
Research to Combat Bioterrorism - Microbial Genomics, Analysis & Modeling	15.00	-	-	-	-	-	-	$15.00	-	-	$15.00
FY 2016 Estimate	**$15.00**	**$199.30**	**$150.55**	**$3.31**	**$3.70**	**$11.00**	**$2.59**	**$385.45**	**$50.39**	**$3.03**	**$438.87**
Protecting Critical Infrastructure & Key Assets	**-**	**$199.30**	**$150.55**	**$3.31**	**$3.70**	**$11.00**	**$2.59**	**$370.45**	**$50.39**	**$3.03**	**$423.87**
Antarctic Physical Security	-	-	-	0.30	-	-	-	$0.30	-	-	$0.30
Counterterrorism	-	27.00	-	-	-	-	-	$27.00	-	-	$27.00
Cybersecurity	-	147.50	5.05	-	2.00	6.00	-	$160.55	-	-	$160.55
Emergency Planning & Response	-	24.80	24.50	-	1.00	-	-	$50.30	-	-	$50.30
Energy Supply Assurance	-	-	26.00	-	-	-	-	$26.00	-	-	$26.00
IT Security	-	-	-	3.01	-	-	2.59	$5.60	0.39	3.03	$9.02
Resilient Infrastructure	-	-	95.00	-	0.70	5.00	-	$100.70	-	-	$100.70
Scholarship for Service/Cybercorps	-	-	-	-	-	-	-	-	50.00	-	$50.00
Defending Against Catastrophic Threats	**$15.00**	**-**	**-**	**-**	**-**	**-**	**-**	**$15.00**	**-**	**-**	**$15.00**
Research to Combat Bioterrorism - Microbial Genomics, Analysis & Modeling	15.00	-	-	-	-	-	-	$15.00	-	-	$15.00
Delta from FY 2016 Estimate to FY 2017 Request	**-**	**$2.00**	**-$1.85**	**-**	**-$0.75**	**-**	**$0.87**	**$0.27**	**$20.13**	**-**	**$20.40**
Protecting Critical Infrastructure & Key Assets	**-**	**$2.00**	**-$1.85**	**-**	**-$0.75**	**-**	**$0.87**	**$0.27**	**$20.13**	**-**	**$20.40**
Antarctic Physical Security	-	-	-	-	-	-	-	-	-	-	-
Counterterrorism	-	-	-	-	-	-	-	-	-	-	-
Cybersecurity	-	2.00	0.15	-	-	-	-	$2.15	-	-	$2.15
Emergency Planning & Response	-	-	-	-	-0.75	-	-	-$0.75	-	-	-$0.75
Energy Supply Assurance	-	-	-	-	-	-	-	-	-	-	-
IT Security	-	-	-	-	-	-	0.87	$0.87	0.13	-	$1.00
Resilient Infrastructure	-	-	-2.00	-	-	-	-	-$2.00	-	-	-$2.00
Scholarship for Service/Cybercorps	-	-	-	-	-	-	-	-	20.00	-	$20.00
Defending Against Catastrophic Threats	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Research to Combat Bioterrorism - Microbial Genomics, Analysis & Modeling	-	-	-	-	-	-	-	-	-	-	-
FY 2017 Request	**$15.00**	**$201.30**	**$148.70**	**$3.31**	**$2.95**	**$11.00**	**$3.46**	**$385.72**	**$70.52**	**$3.03**	**$459.27**
Protecting Critical Infrastructure & Key Assets	**-**	**$201.30**	**$148.70**	**$3.31**	**$2.95**	**$11.00**	**$3.46**	**$370.72**	**$70.52**	**$3.03**	**$444.27**
Antarctic Physical Security	-	-	-	0.30	-	-	-	$0.30	-	-	$0.30
Counterterrorism	-	27.00	-	-	-	-	-	$27.00	-	-	$27.00
Cybersecurity[1]	-	149.50	5.20	-	2.00	6.00	-	$162.70	-	-	$162.70
Emergency Planning & Response	-	24.80	24.50	-	0.25	-	-	$49.55	-	-	$49.55
Energy Supply Assurance	-	-	26.00	-	-	-	-	$26.00	-	-	$26.00
IT Security	-	-	-	3.01	-	-	3.46	$6.47	0.52	3.03	$10.02
Resilient Infrastructure	-	-	93.00	-	0.70	5.00	-	$98.70	-	-	$98.70
Scholarship for Service/Cybercorps	-	-	-	-	-	-	-	-	70.00	-	$70.00
Defending Against Catastrophic Threats	**$15.00**	**-**	**-**	**-**	**-**	**-**	**-**	**$15.00**	**-**	**-**	**$15.00**
Research to Combat Bioterrorism - Microbial Genomics, Analysis & Modeling	15.00	-	-	-	-	-	-	$15.00	-	-	$15.00

Totals may not add due to rounding.

[1]The FY 2017 funding for HSA-Cybersecurity is $162.70 million, of which $160.55 million is discretionary funding and $2.15 million is new mandatory funding.

National Science Foundation
Programs to Broaden Participation
FY 2017 Budget Request to Congress

(Dollars in Millions)

Group/Program	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate: Amount	FY 2017 Request Change Over FY 2016 Estimate: Percent
Total, NSF Broadening Participation Programs	**$765.18**	**$751.40**	**$733.46**	**$29.76**	**$763.22**	**$11.82**	**1.6%**

[1] Includes only new mandatory funding. Excludes H1B Non-Immigrant Petitioner mandatory funds.

NSF has taken a variety of approaches to broaden participation across its many programs. While broadening participation is included in the NSF review criteria, some program announcements and solicitations go beyond the standard criteria. They range from encouraging language to specific requirements. Investments range from capacity building, research centers, partnerships, and alliances to the use of co-funding or supplements to existing awards in the core research programs.

NSF's broadening participation portfolio can be divided into three categories: (1) Focused, (2) Emphases, and (3) Geographic Diversity. The following sections define each of these categories and provide a list of the programs and activities with their respective funding levels that comprise each.

Focused Programs

Focused Programs have broadening participation as an explicit goal of the program and are included at 100 percent of their funding.

(Dollars in Millions)

Group/Program	Amount of Funding Captured	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate: Amount	FY 2017 Request Change Over FY 2016 Estimate: Percent
ADVANCE	100%	$14.89	$14.90	$14.10	-	$14.10	-$0.80	-5.4%
Alliances for Graduate Education & the Professoriate (AGEP)	100%	8.00	8.00	8.00	-	8.00	-	-
AGEP Graduate Research Supplements (AGEP-GRS)	100%	2.47	0.45	2.60	-	2.60	2.15	477.8%
Broadening Participation in Biology Fellowships	100%	3.80	2.50	2.50	-	2.50	-	-
Broadening Participation in Engineering (BPE)	100%	8.86	7.00	7.00	-	7.00	-	-
Career-Life Balance (CLB)	100%	0.49	1.00	1.00	-	1.00	-	-
Centers of Research Excellence in Science & Technology (CREST)	100%	24.01	24.00	24.00	-	24.00	-	-
Excellence Awards in Science & Engineering (EASE)[2]	100%	5.92	5.82	5.82	-	5.82	-	-
Historically Black Colleges & Universities Undergraduate Program (HBCU-UP)	100%	32.04	35.00	35.00	-	35.00	-	-
Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	100%	-	15.50	16.00	-	16.00	0.50	3.2%
Louis Stokes Alliances for Minority Participation (LSAMP)	100%	45.91	46.00	46.00	-	46.00	-	-
Partnerships for Research & Education in Materials (PREM)	100%	7.00	6.80	6.43	-	6.43	-0.37	-5.4%
Partnerships in Astronomy & Astrophysics Research Education (PAARE)	100%	1.00	2.00	1.50	-	1.50	-0.50	-25.0%
SBE Postdoctoral Research Fellowships-Broadening Participation	100%	1.11	1.50	1.50	-	1.50	-	-
SBE Science of Broadening Participation	100%	2.14	1.50	1.50	-	1.50	-	-
Tribal Colleges & Universities Program (TCUP)	100%	13.58	14.00	14.00	-	14.00	-	-
Subtotal, Focused Programs		**$171.21**	**$185.97**	**$186.95**	**-**	**$186.95**	**$0.98**	**0.5%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1B Non-Immigrant Petitioner mandatory funds.

[2] The Excellence Awards in Science and Engineering (EASE) program is comprised of both Presidential Awards for Excellence in Science, Math and Engineering Mentoring (PAESMEM) and Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST).

Emphasis Programs

Emphasis Programs have broadening participation as one of several emphases but broadening participation is not an explicit goal of the program. These programs are included at a percentage of their funding level. The percentage used equals the 3-year average percentage of the programs' award portfolio that meets one the following criteria where an award:

- Was to a Minority Serving Institution (MSI);
- Had at least 50 percent of its principal investigators from an underrepresented group; or
- Had at least 50 percent of the students or postdocs supported by the grant reporting themselves as members of an underrepresented group on project reports.

(Dollars in Millions)

Group/Program	Amount of Funding Captured	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate	
							Amount	Percent
Advancing Informal STEM Learning (AISL)	58%	$31.91	$36.25	$31.90	$4.35	$36.25	-	-
Discovery Research PreK-12 (DR-K12)	59%	49.60	48.82	48.82	-	48.82	-	-
General and Age Related Disabilities Engineering (GARDE)	50%	1.70	1.70	1.70	-	1.70	-	-
Graduate Research Fellowship (GRF)	61%	203.28	202.47	202.62	-	202.62	0.15	0.1%
Robert Noyce Teacher Scholarship Program (NOYCE)	60%	36.64	36.53	36.53	-	36.53	-	-
NSF Scholarships in STEM (S-STEM)[2]	59%	64.51	44.25	44.25	-	44.25	-	-
STEM + Computing Partnerships (STEM+C Partnerships)	55%	40.89	35.41	18.56	16.85	35.41	-	-
Subtotal, Emphasis Programs		**$428.51**	**$405.43**	**$384.38**	**$21.20**	**$405.58**	**$0.15**	**0.0%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1B Non-Immigrant Petitioner mandatory funds.

[2] Amounts for NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) are H-1B Non-Immigrant Petitioner mandatory funds.

Geographic Diversity Programs

Geographic Diversity Programs, EPSCoR, has geographic diversity as an explicit goal of the program and is included at 100 percent of its funding.

(Dollars in Millions)

Group/Program	Amount of Funding Captured	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate	
							Amount	Percent
EPSCoR	100%	$165.46	$160.00	$162.13	$8.56	$170.69	$10.69	6.7%
Subtotal, Geographic Diversity Program		**$165.46**	**$160.00**	**$162.13**	**$8.56**	**$170.69**	**$10.69**	**6.7%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1B Non-Immigrant Petitioner mandatory funds.

National Science Foundation
CoSTEM Inventory and Postdoctoral Fellowship Programs
By Level of Education
FY 2017 Request to Congress
(Dollars in Millions)

		FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change over FY 2016 Estimate: Amount	FY 2017 Request Change over FY 2016 Estimate: Percent
Minority-Serving Institutions		**$45.62**	**$49.00**	**$49.00**	**-**	**$49.00**	-	-
UG	Historically Black Colleges & Universities Undergraduate Program (HBCU-UP)	32.04	35.00	35.00	-	35.00	-	-
UG	Tribal Colleges & Universities Program (TCUP)	13.58	14.00	14.00	-	14.00	-	-
Fellowships & Scholarships		**$624.40**	**$573.76**	**$599.18**	**-**	**$599.18**	**$25.42**	**4.4%**
UG	NSF Scholarships in STEM (S-STEM) (H-1B)[2]	109.34	75.00	75.00	-	75.00	-	-
UG	Robert Noyce Scholarship (Noyce) Program	61.06	60.89	60.89	-	60.89	-	-
G	Cybercorps®: Scholarship for Service (SFS)	45.04	50.00	70.00	-	70.00	20.00	40.0%
G	East Asia & Pacific Summer Institutes for US Grad Students (EAPSI)	1.33	1.80	2.50	-	2.50	0.70	38.9%
G	Graduate Research Fellowship (GRF)	333.24	331.92	332.16	-	332.16	0.24	0.1%
G	NSF Research Traineeship (NRT)[3]	74.40	54.15	58.63	-	58.63	4.48	8.3%
Other Grant Programs		**$588.02**	**$568.82**	**$535.43**	**$38.14**	**$573.57**	**$4.75**	**0.8%**
K-12	Discovery Research PreK-12 (DRK-12)	84.06	82.74	82.74	-	82.74	-	-
K-12	Innovative Technology Experiences for Teachers & Students (ITEST) (H1-B)[2]	29.83	25.00	25.00	-	25.00	-	-
K-12	STEM + Computing (STEM+C) Partnerships	74.34	64.38	33.74	30.64	64.38	-	-
UG	Advanced Technological Education (ATE)	67.67	66.00	66.00	-	66.00	-	-
UG	Improving Undergraduate STEM Education (IUSE)	102.82	105.00	109.00	-	109.00	4.00	3.8%
UG	International Research Experiences for Students (IRES)	6.30	6.50	6.50	-	6.50	-	-
UG	Louis Stokes Alliances for Minority Participation (LSAMP)	45.91	46.00	46.00	-	46.00	-	-
UG	Research Experiences for Undergraduates (REU) - Sites & Supplements	96.82	75.43	75.58	-	75.58	0.15	0.2%
UG	Research Experiences for Teachers (RET) in Engineering and Computer Science	11.35	5.95	6.05	-	6.05	0.10	1.7%
G	Alliances for Graduate Education & the Professoriate (AGEP)	8.00	8.00	8.00	-	8.00	-	-
O&I	Advancing Informal STEM Learning (AISL)	55.01	62.50	55.00	7.50	62.50	-	-
O&I	Excellence Awards in Science & Engineering (EASE)	5.92	5.82	5.82	-	5.82	-	-
O&I	Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	-	15.50	16.00	-	16.00	0.50	3.2%
Subtotal, Above Categories (CoSTEM Inventory Programs)		**$1,258.05**	**$1,191.58**	**$1,183.61**	**$38.14**	**$1,221.75**	**$30.17**	**2.5%**
G	**NSF Postdoctoral Programs**	**$28.13**	**$22.21**	**$22.21**	**-**	**$22.21**	**-**	**-**
	Astronomy & Astrophysics Postdoctoral Fellowships (AAPF)	2.18	2.40	2.40	-	2.40	-	-
	Geosciences Postdoctoral Fellowships	5.03	2.41	2.41	-	2.41	-	-
	International Research Fellowship Program	2.37	2.50	2.50	-	2.50	-	-
	Mathematical Sciences Postdoctoral Research Fellowships (MSPRF)	5.85	4.10	4.10	-	4.10	-	-
	Postdoctoral Research Fellowships in Biology (PRFB)	9.12	7.80	7.80	-	7.80	-	-
	SPRF-Broadening Participation	1.11	1.50	1.50	-	1.50	-	-
	SPRF-Interdisciplinary Research in Behavioral & Social Sciences (SPRF-IBSS)	2.48	1.50	1.50	-	1.50	-	-
K-12 STEM Education Programs (K-12) Subtotal		**$188.22**	**$172.12**	**$141.48**	**$30.64**	**$172.12**	**-**	**-**
Undergraduate STEM Education Programs (UG) Subtotal		**$546.89**	**$489.77**	**$494.02**	**-**	**$494.02**	**$4.25**	**0.9%**
Graduate and Professional STEM Education Programs (G) Subtotal		**$490.14**	**$468.08**	**$493.50**	**-**	**$493.50**	**$25.42**	**5.4%**
Outreach and Informal STEM Education Programs (O&I) Subtotal		**$60.93**	**$83.82**	**$76.82**	**$7.50**	**$84.32**	**$0.50**	**0.6%**
Total, NSF STEM Education		**$1,286.18**	**$1,213.79**	**$1,205.82**	**$38.14**	**$1,243.96**	**$30.17**	**2.5%**

Totals may not add due to rounding.

[1] Includes only new mandatory funds.

[2] H-1B Non-Immigrant Petitioner mandatory funded programs are not new mandatory funding and are included in the FY 2017 Request (Discretionary) column.

[3] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $12.97 million in FY 2015 and $6.35 million in FY 2016.

National Science Foundation
Education and Human Resources Funding by Division and Program
FY 2017 Request to Congress
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	FY 2017 Request Change Over FY 2016 Estimate Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	**$227.20**	**$222.75**	**$201.84**	**$47.44**	**$249.28**	**$26.53**	**11.9%**
Learning and Learning Environments	**25.94**	**25.63**	**42.86**	**9.30**	**52.16**	**$26.53**	**103.5%**
EHR Core Research (ECR): STEM Learning	25.94	25.63	42.86	9.30	52.16	$26.53	103.5%
Broadening Participation & Institutional Capacity	**139.07**	**145.24**	**137.74**	**7.50**	**145.24**	**-**	**-**
Advancing Informal STEM Learning (AISL)	55.01	62.50	55.00	7.50	62.50	-	-
Discovery Research PreK-12 (DRK-12)	84.06	82.74	82.74	0.00	82.74	-	-
STEM Professional Workforce	**62.19**	**51.88**	**21.24**	**30.64**	**51.88**	**-**	**-**
INSPIRE	0.22	-	-	-	-	-	N/A
Science, Technology, Engineering, and Mathematics + Computing (STEM + C) Partnerships	61.97	51.88	21.24	30.64	51.88	-	-
Division of Graduate Education (DGE)	**$286.14**	**$278.48**	**$305.26**	**-**	**$305.26**	**$26.78**	**9.6%**
Learning and Learning Environments	**15.79**	**15.50**	**15.50**	**-**	**15.50**	**-**	**-**
Project and Program Evaluation (PPE)	15.79	15.50	15.50	0.00	15.50	-	-
STEM Professional Workforce	**270.35**	**262.98**	**289.76**	**-**	**289.76**	**$26.78**	**10.2%**
EHR Core Research (ECR): STEM Professional Workforce	16.10	15.97	15.97	0.00	15.97	-	-
Cybercorps®: Scholarship for Service (SFS)	45.04	50.00	70.00	-	70.00	$20.00	40.0%
Graduate Research Fellowship (GRF)	166.52	165.96	166.08	-	166.08	$0.12	0.1%
INSPIRE	1.75	-	-	-	-	-	N/A
NSF Innovation Corps (I-Corps™)	0.20	-	-	-	-	-	N/A
NSF Research Traineeship (NRT)[2]	40.74	31.05	37.71	-	37.71	$6.66	21.4%
Division of Human Resource Development (HRD)	**$143.90**	**$150.23**	**$153.09**	**$2.80**	**$155.89**	**$5.66**	**3.8%**
Learning and Learning Environments	**55.14**	**58.53**	**58.53**	**-**	**58.53**	**-**	**-**
ADVANCE	1.52	1.53	1.53	-	1.53	-	-
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	8.00	8.00	-	8.00	-	-
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	32.04	35.00	35.00	-	35.00	-	-
Tribal Colleges and Universities Program (TCUP)	13.58	14.00	14.00	-	14.00	-	-
Broadening Participation & Institutional Capacity	**58.83**	**61.88**	**64.74**	**2.80**	**67.54**	**$5.66**	**9.1%**
EHR Core Research (ECR): Broadening Participation & Institutional Capacity in STEM	12.92	12.88	14.74	2.80	17.54	$4.66	36.2%
NSF INCLUDES	-	3.00	4.00	-	4.00	$1.00	33.3%
Louis Stokes Alliances for Minority Participation (LSAMP)	45.91	46.00	46.00	-	46.00	-	-
STEM Professional Workforce	**29.93**	**29.82**	**29.82**	**-**	**29.82**	**-**	**-**
Centers for Research Excellence in Science and Technology (CREST)	24.01	24.00	24.00	-	24.00	-	-
Excellence Awards in Science and Engineering (EASE)	5.92	5.82	5.82	0.00	5.82	-	-
Division of Undergraduate Education (DUE)	**$229.08**	**$228.54**	**$238.68**	**$3.75**	**$242.43**	**$13.89**	**6.1%**
Learning and Learning Environments	**100.00**	**100.10**	**110.24**	**3.75**	**113.99**	**$13.89**	**13.9%**
EHR Core Research (ECR): STEM Learning Environments	16.16	13.10	17.74	3.75	21.49	$8.39	64.0%
Improving Undergraduate STEM Education (IUSE)	83.84	87.00	92.50	0.00	92.50	**$5.50**	**6.3%**
STEM Professional Workforce	**129.08**	**128.44**	**128.44**	**-**	**128.44**	**-**	**-**
Advanced Technological Education (ATE)	67.67	66.00	66.00	-	66.00	-	-
NSF Innovation Corps (I-Corps™)	0.35	1.55	1.55	-	1.55	-	-
Robert Noyce Teacher Scholarship Program (Noyce)	61.06	60.89	60.89	-	60.89	-	-
Total, EHR	**$886.33**	**$880.00**	**$898.87**	**$53.99**	**$952.86**	**$72.86**	**8.3%**
Total, Learning and Learning Environments	$196.88	$199.76	$227.13	$13.05	$240.18	**$40.42**	**20.2%**
Total, Broadening Participation & Institutional Capacity	$197.90	$207.12	$202.48	$10.30	$212.78	**$5.66**	**2.7%**
Total, STEM Professional Workforce	$491.55	$473.12	$469.26	$30.64	$499.90	**$26.78**	**5.7%**

Totals may not add due to rounding.

[1] Includes only new mandatory funds. Does not include H-1B Non-Immigrant Petitioner mandatory funded programs: 1) Scholarships in STEM and 2) InnovativeTechnology Experiences for Teachers and Students.

[2] FY 2015 funding for Integrative Graduate Education and Research Traineeship (IGERT) ($4.60 million) is included in the NRT line.

National Science Foundation
Research Infrastructure (RI) Funding by Account and Activity
FY 2017 Request to Congress
(Dollars in Millions)

	FY 2015 Actual	FY 2015 Actual RI Funding	**FY 2016 Estimate**	FY 2016 Estimate RI Funding	**FY 2017 Request (Discretionary)**	FY 2017 Request (Discretionary) RI Funding	**FY 2017 Request (Mandatory)[1]**	FY 2017 Request (Mandatory) RI Funding[1]	**FY 2017 Request**	FY 2017 Request RI Funding	**FY 2017 Request RI change over FY 2016 Estimate RI** Amount	Percent
BIO	**$736.19**	$96.63	**$744.17**	$148.89	**$745.73**	$152.95	**$44.79**	-	**$790.52**	$152.95	$4.06	2.7%
CISE	**932.98**	159.46	**935.82**	167.90	**938.43**	172.83	**56.37**	-	**994.80**	172.83	4.93	2.9%
ENG	**923.53**	33.52	**916.19**	28.33	**946.41**	28.33	**56.32**	-	**1,002.73**	28.33	-	-
GEO	**1,319.04**	709.44	**1,318.54**	692.27	**1,319.56**	695.32	**79.27**	26.20	**1,398.83**	721.52	29.25	4.2%
MPS	**1,376.32**	333.51	**1,349.15**	341.36	**1,355.06**	361.15	**81.39**	-	**1,436.45**	361.15	19.79	5.8%
SBE	**276.19**	62.03	**272.20**	60.91	**272.41**	61.83	**16.36**	-	**288.77**	61.83	0.92	1.5%
OISE	**48.46**	0.10	**49.10**	0.10	**49.10**	0.10	**2.95**	-	**52.05**	0.10	-	-
IA	**427.46**	77.21	**447.06**	78.67	**451.30**	92.27	**8.56**	-	**459.86**	92.27	13.60	17.3%
U.S. Arctic Research Commission	**1.41**	-	**1.43**	-	**1.43**	-	**-**	-	**1.43**	-	-	N/A
Research & Related Activities	**$6,041.57**	$1,471.90	**$6,033.65**	$1,518.43	**$6,079.43**	$1,564.78	**$346.01**	$26.20	**$6,425.44**	$1,590.98	$72.55	4.8%
Education & Human Resources	**$886.33**	-	**$880.00**	-	**$898.87**	-	**$53.99**	-	**$952.86**	-	-	N/A
Major Research Equipment & Facilities Construction	**$144.76**	$144.76	**$200.31**	$200.31	**$193.12**	$193.12	**-**	-	**$193.12**	$193.12	-$7.19	-3.6%
Agency Operations & Award Management	**$306.56**	-	**$330.00**	-	**$373.02**	-	**-**	-	**$373.02**	-	-	N/A
National Science Board	**$4.15**	-	**$4.37**	-	**$4.38**	-	**-**	-	**$4.38**	-	-	N/A
Office of Inspector General	**$14.60**	-	**$15.16**	-	**$15.20**	-	**-**	-	**$15.20**	-	-	N/A
Total, National Science Foundation	**$7,397.97**	$1,616.66	**$7,463.49**	$1,718.74	**$7,564.02**	$1,757.90	**$400.00**	$26.20	**$7,964.02**	$1,784.10	**$65.36**	**3.8%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1-B Non-Immigrant Petitioner mandatory funds.

National Science Foundation
Research Infrastructure Summary
FY 2017 Budget Request to Congress
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request change over FY 2016 Estimate Amount	Percent
Facilities	**$894.64**	**$977.10**	**$1,007.60**	**$15.10**	**$1,022.70**	**$45.60**	**4.7%**
Academic Research Fleet[2]	79.87	83.80	82.80	-	82.80	-1.00	-1.2%
Arecibo Observatory	8.01	8.20	8.30	-	8.30	0.10	1.2%
AST Portfolio Review Implementation	0.16	7.00	7.00	-	7.00	-	-
Cornell High Energy Synchrotron Source (CHESS)[3]	21.97	18.03	20.00	-	20.00	1.97	10.9%
Gemini Observatory	20.61	19.88	20.42	-	20.42	0.54	2.7%
Geodesy Advancing Geosciences and EarthScope (GAGE)	11.58	11.58	11.58	1.50	13.08	1.50	13.0%
IceCube Neutrino Observatory (IceCube)	6.90	6.90	7.00	-	7.00	0.10	1.4%
International Ocean Discovery Program (IODP)	48.00	48.00	48.00	-	48.00	-	-
Large Hadron Collider (LHC)	18.00	18.00	18.00	-	18.00	-	-
Laser-Interferometer Gravitational-wave Observatory (LIGO)	33.00	39.43	39.43	-	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)[4]	35.92	22.78	35.78	-	35.78	13.00	57.1%
National Nanotechnology Coordinated Infrastructure (NNCI)	15.02	15.46	15.46	-	15.46	-	-
National Superconducting Cyclotron Laboratory (NSCL) (MSU Cyclotron)	23.00	24.00	24.50	-	24.50	0.50	2.1%
Natural Hazards Engineering Research Infrastructure (NHERI)	18.24	12.50	12.50	-	12.50	-	-
Ocean Observatories Initiative (OOI)	55.00	55.00	50.00	-	50.00	-5.00	-9.1%
Other Facilities[5]	2.77	2.77	2.79	-	2.79	0.02	0.7%
Polar Facilities and Logistics	314.54	286.57	296.07	11.00	307.07	20.50	7.2%
Seismological Facilities for Advancement of Geoscience & EarthScope (SAGE)	24.35	24.35	24.35	2.60	26.95	2.60	10.7%
Other Facilities Investments							
Major Research Equipment and Facilities Construction[6]	154.01	258.35	276.12	-	276.12	17.77	6.9%
Facilities Pre-Construction Planning[7]	3.70	14.50	7.50	-	7.50	-7.00	-48.3%
Federally Funded R&D Centers	**$220.25**	**$217.62**	**$219.02**	**$1.30**	**$220.32**	**$2.70**	**1.2%**
National Center for Atmospheric Research (NCAR)	98.70	99.70	99.70	1.30	101.00	1.30	1.3%
National Optical Astronomy Observatories (NOAO)	25.50	21.60	21.83	-	21.83	0.23	1.1%
National Radio Astronomy Observatories (NRAO)[8]	83.31	82.08	75.25	-	75.25	-6.83	-8.3%
Other Astronomical Facilities	-	-	11.50	-	11.50	11.50	N/A
National Solar Observatory (NSO)[9]	8.00	9.50	6.00	-	6.00	-3.50	-36.8%
Science & Technology Policy Institute (STPI)	4.74	4.74	4.74	-	4.74	-	-
Other Research Instrumentation and Infrastructure	**$503.53**	**$525.78**	**$533.75**	**$9.80**	**$543.55**	**$17.77**	**3.4%**
Major Research Instrumentation (MRI)	74.22	75.69	90.00	-	90.00	14.31	18.9%
Midscale Research Infrastructure	-	48.02	52.98	-	52.98	4.96	10.3%
National Center for Science & Engineering Statistics (NCSES)	45.37	45.21	46.13	-	46.13	0.92	2.0%
NCSES Science of Science and Innovation Policy (SciSIP) Activities	4.95	4.95	4.95	-	4.95	-	-
Networking and Computational Resources Infrastructure and Services	116.45	123.80	123.80	-	123.80	-	-
Polar Environment, Health, and Safety (PEHS)	6.66	6.62	6.62	0.50	7.12	0.50	7.6%
Research Resources[10]	255.05	219.74	207.52	9.30	216.82	-2.92	-1.3%
Research Resources – Public Access Initiative	0.82	1.75	1.75	-	1.75	-	-
Subtotal, Research Infrastructure Support	**$1,618.42**	**$1,720.50**	**$1,760.37**	**$26.20**	**$1,786.57**	**$66.07**	**3.8%**
Research Infrastructure Stewardship Offset	**-$1.76**	**-$1.76**	**-$2.47**	**-**	**-$2.47**	**-$0.71**	**40.3%**
RESEARCH INFRASTRUCTURE TOTAL	**$1,616.66**	**$1,718.74**	**$1,757.90**	**$26.20**	**$1,784.10**	**$65.36**	**3.8%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H1-B Non-Immigrant Petitioner mandatory funds.

[2] Academic Research Fleet funding includes ship operations and upgrades. Regional Class Research Vessels (RCRV) funding is no longer included on this line as it is proposed for an FY 2017 MREFC new construction start.

[3] Forward funding for the Cornell High Energy Synchrotron Source (CHESS) of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[4] Forward funding for the National High Magnetic Field Laboratory (NHMFL) of $11.88 million in FY 2015 reduced the amount required in FY 2016.

[5] Other Facilities includes ongoing MPS support for the Center for High Resolution Neutron Scattering (CHRNS).

[6] Funding levels for MREFC Projects in this table include support for: a) concept and development associated with ongoing and requested MREFC projects provided through the R&RA account; b) initial support for operations and maintenance provided through the R&RA account; and c) implementation support provided through the MREFC account.

[7] Pre-construction planning includes funding for potential next generation multi-user facilities. This line reflects funding for Antarctic Infrastructure Modernization for Science (AIMS) for all three years and the Large Hadron Collider (LHC) upgrade for FY 2017 only. The LHC upgrade will be funded at $2.50 million in FY 2017.

[8] Funding for the National Radio Astronomy Observatory (NRAO) includes operations and maintenance support for the Atacama Large Millimeter Array (ALMA). The substantial drop in support in FY 2017 is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now included under "Other Astronomical Facilities" in this table.

[9] National Solar Observatory (NSO) totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $14.0 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured within the total presented on the MREFC line.

[10] Funding for Research Resources includes support for the operation and maintenance of minor facilities, infrastructure and instrumentation, field stations, museum collections, etc.

National Science Foundation Current Authorizations

(Dollars in Millions)

LEGISLATION	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Authorization Levels FY 2015	FY 2016	FY 2017
National Science Foundation Act of 1950 (P.L.81-507)[1]						
Scholarships and Graduate Fellowships				*within limits of funds made available for this purpose*		
General Authority				*within the limits of available appropriations*		
Administering Provisions				*to make such expenditures as may be necessary*		
International Cooperation and Coordination with Foreign Policy				*within the limit of appropriated funds*		
Contract Arrangements				*utilize appropriations available*		
SBIR and STTR reauthorized under the National Defense Authorization Act for Fiscal Year 2012, (P.L. 112-81)						
Small Business Innovation Research (SBIR) Program[2]	**$156.28**	**$163.97**	**$186.97**	*2.9% of research funds in 2015, 3.0% in 2016, 3.2% in 2017*		
Small Business Technology Transfer (STTR) Program[2]	**$20.83**	**$24.59**	**$26.29**	*0.40% of research funds in 2015, 0.45% in 2016 and 2017*		
National Windstorm Impact Reduction Act Reauthorization of 2015 (P.L. 114-52)[3]	*	*	*	*$9.68*	*$9.68*	*$9.68*
Engineering and the atmospheric sciences to improve the understanding of the behavior of windstorms and their impact on buildings, structures, and lifelines; and Economic and social factors influencing windstorm risk reduction measures.						

[1] Organic legislation establishing NSF.

[2] SBIR and STTR are authorized through September 30, 2017.

[3] Budget levels noted with * were not available at the time of publishing the FY 2017 Budget Request.

RESEARCH AND RELATED ACTIVITIES (R&RA) $6,425,440,000

+$391,790,000 / 6.5%

The FY 2017 Budget Request for the Research and Related Activities (R&RA) account is $6,425.44 million, of which $6,079.43 billion is discretionary funding and $346.01 million is new mandatory funding. The FY 2017 Budget Request is an increase of $391.79 million above the FY 2016 Estimate level of $6,033.65 million. Funding within the R&RA Appropriation enables U.S. leadership and progress across the frontiers of scientific and engineering research and education.

In FY 2017, NSF will continue its longstanding commitment to investing in learning and discovery that will grow our economy, sustain our competitive advantage, and enable America to remain the world leader in innovation. It embraces the challenge of ensuring that scientific discovery and technological breakthroughs remain the primary engines for expanding the frontiers of human knowledge and responding to the challenges of the 21st century.

In FY 2017, funding within the broad and flexible R&RA account includes agency-wide support for research priorities such as advanced manufacturing, clean energy technology, climate science, cyberinfrastructure, cybersecurity, resilience to extreme natural and human-made events, and cognitive science and neuroscience. A major emphasis is support for young scientists and engineers engaged in research and teaching at the forefront of science, technology, engineering, and mathematics.

R&RA Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
Biological Sciences	$736.19	$744.17	$790.52	$46.35	6.2%
Computer & Information Science & Engineering	932.98	935.82	994.80	58.98	6.3%
Engineering	923.53	916.19	1,002.73	86.54	9.4%
Geosciences	1,319.04	1,318.54	1,398.83	80.30	6.1%
Mathematical & Physical Sciences	1,376.32	1,349.15	1,436.45	87.30	6.5%
Social, Behavioral & Economic Sciences	276.19	272.20	288.77	16.57	6.1%
Office of International Science and Engineering	48.46	49.10	52.05	2.95	6.0%
Integrative Activities	427.46	447.06	459.86	12.80	2.9%
U.S. Arctic Research Commission	1.41	1.43	1.43	-	-
Total, R&RA	**$6,041.57**	**$6,033.65**	**$6,425.44**	**$391.79**	**6.5%**

Totals may not add due to rounding.

RESEARCH AND RELATED ACTIVITIES

Appropriations Language

For necessary expenses in carrying out the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), and Public Law 86–209 (42 U.S.C. 1880 et seq.); services as authorized by section 3109 of title 5, United States Code; maintenance and operation of aircraft and purchase of flight services for research support; acquisition of aircraft; and authorized travel; ~~$6,033,645,000,~~*$6,079,430,000,* to remain available until September 30, ~~2017,~~*2018,* of which not to exceed ~~$540,000,000~~*$544,000,000* shall remain available until expended for polar research and operations support, and for reimbursement to other Federal agencies for operational and science support and logistical and other related activities for the United States Antarctic

program: *Provided*, That receipts for scientific support services and materials furnished by the National Research Centers and other National Science Foundation supported research facilities may be credited to this appropriation.
Science Appropriations Act, 2016.

Research and Related Activities
FY 2017 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Transfers	Obligations Actual/ Estimates
FY 2015 Appropriation	$5,933.65	$57.66	-$10.08	$60.35	$0.00	$6,041.57
FY 2016 Estimate	6,033.65	10.08				6,043.73
FY 2017 Discretionary	*6,079.43*					
FY 2017 Mandatory	*346.01*					
FY 2017 Total Request	6,425.44					6,425.44
$ Change from FY 2016 Estimate						$381.71
% Change from FY 2016 Estimate						6.3%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Research and Related Activities (R&RA)** account, $11.17 million (including $1.09 million in reimbursable funds) was carried over into FY 2016.

- Directorate for Geosciences Polar Programs (no-year funding)
  - Amount: $5.05 million
  - Reason: These funds are recoveries from prior year obligations.
  - Anticipated Obligation: FY 2016 Quarter 2

- Office of Integrative Activities
  - Amount: $2.55 million
  - Reason: Carryover balance is for the Major Research Instrumentation Program. Several MRI awards were not ready for obligation before the close of FY 2015. Funds will be used for FY 2016 awards.
  - Anticipated Obligation: FY 2016 Quarter 2

- National Coordination Office for Networking and Information Technology Research and Development (NCO/NITRD)
  - Amount: $439,100
  - Reason: Funding provided for the operations of NCO/NITRD.
  - Anticipated Obligation: FY 2016 Quarter 2

- National Nanotechnology Coordination Office (NNCO)
  - Amount: $22,000
  - Reason: Funding provided for the operations of NNCO.
  - Anticipated Obligation: FY 2016 Quarter 2

The remaining R&RA carryover of $2.02 million consists of funds from throughout the Foundation for projects that were not ready for obligation in FY 2015.

DIRECTORATE FOR BIOLOGICAL SCIENCES (BIO) $790,520,000 +$46,350,000 / 6.2%

BIO Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Molecular & Cellular Biosciences (MCB)	$134.95	$135.53	$136.77	$1.24	0.9%
Integrative Organismal Systems (IOS)	215.12	214.32	215.40	1.08	0.5%
Environmental Biology (DEB)	143.76	144.03	145.17	1.14	0.8%
Biological Infrastructure (DBI)	144.14	144.68	135.74	-8.94	-6.2%
Emerging Frontiers (EF)	98.22	105.61	157.44	51.83	49.1%
Total, BIO	**$736.19**	**$744.17**	**$790.52**	**$46.35**	**6.2%**

Totals may not add due to rounding.

About BIO

The FY 2017 Budget Request for the Directorate for Biological Sciences (BIO) is $790.52 million, of which $745.73 million is discretionary funding and $44.79 million is new mandatory funding. The major focus of the mandatory funding is support for core activities and support of early career investigators. Special emphasis will be placed on research that aligns with the new BIO emphasis on Rules of Life that includes areas such as the genotype to phenotype challenge, plant and microbial sciences, including study of the microbiome, synthetic biology, and the origin of life. Support for early investigators is important to ensure adequate numbers of researchers as these research problems will require a long-term investment in tackling difficult and complex questions.

BIO's top priority is core research across biology. Current funding rates have become dangerously low, at or near single digits in most programs (when pre-proposals are counted). U.S. academic research in the biological sciences depends on NSF funding; 68 percent of academic basic research in non-medical biology is supported by NSF. BIO considers this role essential to the health of fundamental biological research at U.S. universities and colleges. Broad support for biology is necessary to produce the knowledge that will address national needs in agriculture, health, environment, and continuing innovation for the bioeconomy, which has already shown progress in areas such as biofuels, biorenewable chemicals, and nanotechnology.

BIO increasingly supports projects that address comprehensive questions involving multiple types of data acquisition and levels of analysis. Many of these projects are becoming larger and more collaborative both within the biological sciences and with other fundamental disciplines. NSF is one of the few agencies where support for such integration across disciplines is possible, but achieving this requires new funding strategies and portfolio realignment within BIO. These new strategies are reflected in the FY 2017 Budget Request.

In FY 2017, BIO will begin a new emphasis in understanding the "Rules of Life," necessary to inform our collaborations with the Directorates for Engineering (ENG), Mathematical and Physical Sciences (MPS), and Computer and Information Science and Engineering (CISE).

FY 2017 priorities for BIO include:

Rules of Life (+$13.0 million): Support for this new emphasis includes research areas such as the genotype to phenotype challenge, plant and microbial sciences, including the study of microbiomes, synthetic biology, origins of life, and developing biological theory as a framework for the rules of life. Quantitative approaches that integrate the mathematical and physical sciences, computer science, and engineering into advancing basic biological understanding underpinning the study of the rules of life will be encouraged. In addition, BIO will emphasize support for early career scientists through enhanced funding for principal investigators, new efforts to train graduate students, and targeted support for postdoctoral fellows.

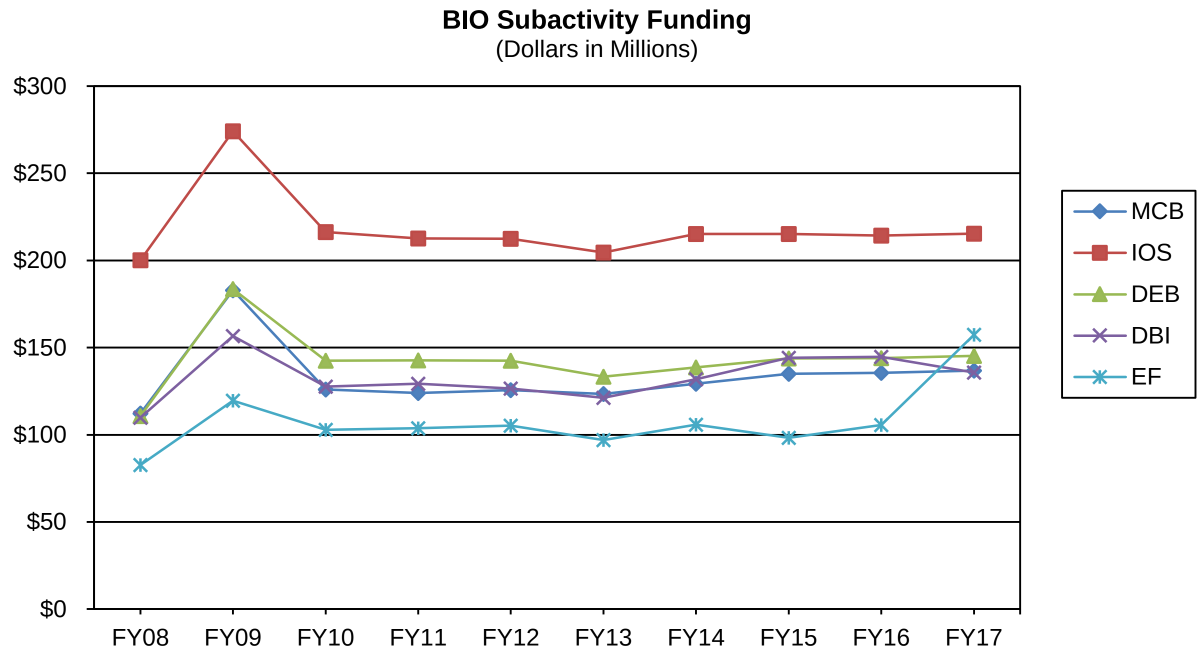
<u>National Ecological Observatory Network (NEON) (+$20.96 million):</u> In FY 2017, as NEON nears completion, BIO will assume full operations and maintenance funding responsibility for NEON, including increased funding for oversight. With the need for increased oversight, BIO will transfer program management for NEON operations from Emerging Frontiers (EF) into the Division of Biological Infrastructure (DBI), which has long-standing experience managing cooperative agreements and infrastructure, such as Science and Technology Centers (STCs), iPlant, and other BIO Centers for Analysis and Synthesis. Funding for early NEON science, including continuing support for the MacroSystems Biology (MSB) program, remains a priority. NSF is in the process of evaluating new managing organizations for NEON operations and maintenance; until the final organization is selected and costs determined, funds are being retained in EF. For more information on NEON, see the Major Research Equipment and Facilities Construction (MREFC) chapter.

<u>Understanding the Brain (UtB), including the BRAIN Initiative (+$1.62 million):</u> This cross-agency priority will be enhanced in FY 2017. BIO funding for UtB, including the BRAIN Initiative, increases to support investment strategies designed to enable the transformational research, engineering, infrastructure development, and training required to accomplish the overall multi-year goal. A new solicitation for Neuro-Tech Hubs will be issued to further support the development of a brain observatory. Additional information for UtB is available in the NSF-Wide Investments chapter.

<u>Graduate Students:</u> Graduate student costs on BIO research awards, including reimbursement for tuition, have increased. Within BIO, there is concern about the quality of student training via traditional graduate research experiences (i.e. research assistants on research grants) versus more independent approaches (i.e. fellowships and traineeships). BIO is concerned that graduate training supported on BIO research grants is not responsive to areas of long-term research need, including improved diversity in science and engineering education, nor is it providing essential information about long-term academic and non-academic career opportunities. In FY 2017, BIO proposes limiting the investment in graduate students on research grants. In parallel, BIO will endorse an increased number of Graduate Research Fellowship (GRF) awards for students in biology, will slightly increase its funding for the NSF Research Traineeship (NRT) program, and begin support for a new pilot program, BIO Research Training Grant (RTG), which is expected to integrate with NRT in later years following the initial pilot.

<u>Innovation:</u> Through funding in EF, BIO has invested in Ideas Labs in multiple areas of scientific inquiry, including photosynthesis, nitrogen fixation, and olfaction, this latter activity as part of the President's BRAIN Initiative. In FY 2017, a new Ideas Lab, in collaboration with NASA, is planned on the Origins of Life. NASA and NSF have signed an interagency agreement to encourage and support interaction among NASA and NSF personnel about origin of life research. A joint Ideas Lab is in the planning stages to be funded in FY 2017 as a mechanism for identifying and funding potentially transformative research to address grand challenge questions on the origin of life. The aim of this Ideas Lab is to foster the development of a theoretical framework that encompasses the "metabolism first" and "RNA first" theories for the origin of life by stimulating creative thinking and new research on the earliest events leading to life on Earth. Understanding plausible pathways for the origin of life would contribute directly to our understanding of the indispensable properties of life on Earth and inform our search for life on other worlds. Additional funding for innovation activities will continue with a focus on rules of life.

Early Career Awards and Enhanced Research Investment (+$44.79 million): Support for early career awardees and research on the rules of life will be enhanced. BIO broadly defines early career investigators as 1) first-time NSF postdoctoral fellows, 2) first-time federal grantees (excluding postdoctoral fellowships awards), and 3) second-time NSF grantees (i.e., NSF awardees who submit a proposal within one year - before or after - the expiration date of their first NSF award (excluding postdoctoral fellowship awards)). Funds will be used to encourage BIO's core programs to support meritorious investigators in these three early career categories. Priority will be placed on the new BIO emphasis Rules of Life.



FY 2009 funding reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- MCB's FY 2017 Request ($136.77 million) will focus support for research at the interface of biology with the quantitative and predictive sciences to enhance understanding into the fundamental molecular and cellular principles of life representing the heart of the new Rules of Life emphasis as well as the bioeconomy. Funding for graduate students on research grants will be limited allowing those funds to be redirected to other emphasis areas. MCB will fund advanced manufacturing research through the Research at the Interface of Biology, Mathematics, and Physical Sciences (BioMaPS) cross-foundational activity and Engineering Biology, a part of the Advanced Manufacturing initiative in Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS). MCB will support research on computational design of biological systems (from proteins to communities of organisms) that could be used to produce fuels, chemicals and materials, and the development of tools and standards in synthetic biology as an approach to the rapid development of biomanufacturing platforms. MCB's contributions include research such as computational mining of the biological data from diverse biological systems to identify inspirations for the design and synthesis of new materials with defined properties and capabilities, and predictive synthetic biology to design new nanomaterials, particularly based on photosynthesis and other biological processes. Research in these areas provides important foundational information towards clean energy technologies.

- IOS's FY 2017 Request ($215.40 million) provides support for neural, developmental, physiological, biomechanical, and behavioral processes that characterize organisms, and how they are integrated to result in the dynamic stability of whole organisms. Achieving such a systems-level understanding of organisms is relevant to, and will help advance, the understanding of genomes to phenomes, as well as contribute substantively to understanding the rules of life. IOS' investment in neuroscience is supported and complemented by BIO's BRAIN Initiative activities, a significant portion of which ($16.10 million of $19.54 million total for BIO) are funded through Emerging Frontiers. All IOS programs, particularly the Plant Genome Research Program (PGRP), will encourage the use of synthetic biology approaches to alter and manipulate the complex interactions of cellular and organismal components to reveal systems dynamics and emergent properties. PGRP also will enhance support for research in areas that will provide important foundational information towards clean energy technologies.

- DEB's FY 2017 Request ($145.17 million) will emphasize fundamental research on complex ecological and evolutionary processes and on how their relationships and feedbacks shape biodiversity and explain the dynamics of populations, species, communities, and ecosystems across broad spatial, temporal, and phylogenetic scales. This research is central to the new Rules of Life emphasis. This research will improve our ability to understand the reciprocal interactions between living systems and a changing environment, and inform essential considerations of environmental sustainability. DEB's financial investment in graduate students on research awards will be limited allowing those funds to be redirected to other emphasis areas. DEB will sustain support for the Dimensions of Biodiversity and the Dynamics of Coupled Natural and Human Systems (CNH) programs, and will continue to invest in coordinated efforts to link legacy and current data streams to enable integrative synthesis. DEB will enhance support for research in areas that will provide important foundational information towards clean energy technologies.

- DBI's FY 2017 Request ($135.74 million) empowers biological discovery by supporting the development and enhancement of biological research resources, human capital, and centers. In FY 2017, BIO plans to assess the effectiveness of current DBI programs towards the evolving needs of the biology community, which have become more complex, diverse, and centered on data storage, access, and analysis. Evaluating current programs, assessing where investments can make a difference in the long term resource needs, and developing a robust STEM pipeline will be a priority. BIO will use FY 2017 to reexamine the goals and objectives of many of DBI's longstanding research resource and human resource programs. Emphasis will be placed on evaluation, impact, and scalability, to gauge where support from BIO makes a difference and can be leveraged. Several programs will be put on a biennial competition schedule during their assessment and evaluation. BIO expects this assessment to be complete in time to inform the FY 2018 budget.

  In addition, DBI is limiting the financial investment of graduate students supported on research grants. A new BIO Research Training Grant program (+$6.16 million) is being introduced.

- EF's FY 2017 Request ($157.44 million) supports a number of limited-term activities, thus allowing for repurposing of funds towards new emphases including support for facilities. NSF-wide activities supported within EF include: the BRAIN Initiative, BioMaPS, and INFEWS. EF also will maintain investment in Dimensions of Biodiversity, the last BIO program within SEES as this activity continues to phase-down. In FY 2017, NEON Operations and Maintenance (O&M) increases to a total of $65.0 million, as construction nears completion and NEON moves into full operations. Support for the MSB program and early NEON science ($10.0 million) will be supported as NEON cross-continental data is available for research. A majority of the increase in EF (+$44.79 million) will be used to support additional early career researchers and to fund additional awards across BIO as part of the Rules of Life emphasis.

Major Investments

BIO Major Investments

(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
ADVANCE	$1.25	$1.25	$1.25	-	-
BioMaPS	14.53	16.81	16.81	-	-
CAREER	40.53	34.60	35.07	0.47	1.4%
CEMMSS	4.99	5.48	5.48	-	-
Advanced Manufacturing	*2.84*	*3.33*	*3.33*	-	-
Clean Energy Technology	48.31	48.39	79.22	30.83	63.7%
CIF21	3.75	8.39	8.39	-	-
Microbiome	-	13.64	16.37	2.73	20.0%
NSF I-Corps™	0.85	1.00	1.00	-	-
NSF INCLUDES	-	1.47	1.40	-0.07	-4.8%
INFEWS	-	7.50	10.00	2.50	33.3%
IUSE	1.13	2.50	2.50	-	-
NRT[1]	3.24	2.33	2.82	0.49	21.0%
SEES	21.00	17.50	17.50	-	-
Understanding the Brain	38.48	44.38	46.00	1.62	3.7%
BRAIN Initiative	*11.50*	*18.05*	*19.54*	*1.49*	*8.3%*

Major investments may have funding overlap and thus should not be summed.

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $1.85 million in FY 2015 and $1.62 million in FY 2016.

- ADVANCE ($1.25 million): BIO will continue to participate in the NSF-wide program ADVANCE as part of its ongoing commitment to broaden participation to build strategies and models to increase the participation, retention, and advancement of women in all STEM academic careers.

- BioMaPS ($16.81 million): This NSF-wide investment seeks to discover fundamental new knowledge to enable innovation in national priorities such as clean energy, climate science, and advanced manufacturing. In FY 2017, BIO will sustain support for this activity. One area of emphasis will be synthetic biology, which is a convergent area at the intersection of biology, engineering, and physical sciences that informs our ability to design and build novel biological functions and systems using engineering principles. Synthetic biology promises to develop a wide range of economically viable agricultural, industrial, and environmental, energy, and health applications. Because many synthetic biology products, such as food additives, biofuels, drugs, and applications to prevent insect borne diseases are now close to commercialization, it is becoming increasingly essential and urgent that we understand environmental, evolutionary, and societal contexts of synthetic biology products and organisms. In addition, synthetic biology is also opening up new avenues of enquiry and experimental approach that promise to advance fundamental knowledge about biological processes linking genome to phenome as well as other areas of investigation that encompass the rules of life.

- CAREER ($35.07 million): BIO's CAREER awards support young investigators who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations. In FY 2017, BIO will increase support for CAREER by $470,000 over the FY 2016 Estimate.

- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) ($5.48 million): BIO's support will enable breakthrough materials through research on topics such as computational mining of genomic data from diverse biological systems to identify inspirations for the design of new materials, or predictive synthetic biology to design new nanomaterials, particularly based on photosynthesis and other biological processes. In FY 2017, BIO will continue its interagency collaborations in the area of engineering biology related to advanced biomanufacturing. ENG and BIO will continue to collaborate in funding an Industry/University Cooperative Research Center (I/UCRC) in the area. For more information on CEMMSS, see the NSF-wide Investments Chapter.

- Advanced Manufacturing ($3.33 million): BIO will support advanced manufacturing research through BioMaPS and CEMMSS. In collaboration with ENG, BIO supports advances in standards in synthetic biology and the development of tools that will advance biomanufacturing and the development of novel biomaterials that will support the development of a thriving bioeconomy.

- Clean Energy Technology ($79.22 million): BIO support for clean energy technology increases by $30.83 million over the FY 2016 Estimate for fundamental research in areas such as systems and synthetic biology to streamline and scale the metabolic and energetic potential of living organisms (e.g., microbes, fungi, algae, and plants) to produce non-petroleum based sources of important chemicals/materials, feed stocks, and fuels. Bioinspired design of new proteins and other complex biomaterials that can transform light into energy will also be supported. Investigations to assess the impact of fuel and/or bio-renewable chemical production on genome stability, fitness, and phenotype of the production organisms are of interest, as are studies to assess the potential environmental impacts of these technologies.

- Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) ($8.39 million): BIO will sustain support for new midscale projects to advance data, software, and collaborative infrastructure in support of several priority areas, such as Rules of Life, Understanding the Brain, and Genotype to Phenotype, through the Advances in Biological Informatics Program, BIO Synthesis Centers, as well as ongoing solicitations, i.e. Software Infrastructure for Sustained Innovation (SI^2). In FY 2017, SI^2 will begin to focus on software infrastructure for major projects and awards including STCs, iPlant, and Major Research Facilities and Construction (MREFC) projects such as NEON. For more information on CIF21, see the NSF-wide Investments Chapter.

- Microbiome ($16.37 million): In FY 2017, support for microbiome research will increase +$2.73 million. Microbiomes are the collective microbial partners that live in, on, and around plants and animals. Microbiome investments support research on the role of microbes in plant and animal function, productivity, health, and resilience to environmental change, as well as microbes' role in soil and marine ecosystems. Studies of microbiomes occur on a broad range of scales from metagenomics, which looks at the entirety of collective genomes in microbial communities, to individual community composition and collective metabolic activity. A joint solicitation between BIO IOS and USDA NIFA called Plant Biotic Interactions (PBI) will be issued in FY 2016, with initial awards funded in FY 2017.

- NSF Innovation Corps (I-Corps™) ($1.0 million): BIO will sustain support for I-Corps™ nodes and grants that test the feasibility of commercial prototypes developed from NSF/BIO-supported research. For more information on NSF I-Corps™, see the NSF-wide Investments Chapter.

- NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) ($1.40 million): In FY 2017, BIO will participate in this NSF-wide effort to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or underrepresented in STEM fields. For more information on NSF INCLUDES, see the NSF-wide Investments Chapter.

- Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) ($10.0 million): The food-energy-water emphasis will be stressed in NSF-wide and BIO specific programs, such as Dynamics of Coupled Natural and Human Systems (CNH), Macrosystems Biology (MSB), and a phytobiome Dear Colleague Letter. For more information on INFEWS, see the NSF-wide Investments Chapter.

- Improving Undergraduate STEM Education (IUSE) ($2.50 million): DBI will continue to support activities related to undergraduate biology education through Research Collaboration Networks-Undergraduate Biology Education (RCN-UBE). For more information regarding IUSE, see the NSF-Wide Investments chapter.

- NSF Research Traineeship (NRT) ($2.82 million): BIO will participate in the NSF-wide program, NRT. For more information regarding NRT, see the Major Investments in Science, Technology, Engineering, and Mathematics (STEM) Graduate Education narrative in the NSF-Wide Investments chapter.

- Science, Engineering, and Education for Sustainability (SEES) ($17.50 million): BIO will sustain support for the Dimensions of Biodiversity while phasing down support for other SEES programs. For more information on SEES, see the NSF-Wide Investments Chapter.

- Understanding the Brain (UtB) ($46.0 million): BIO continues support for this cross-foundation activity. Investments in research on mapping circuits that drive behavior in a variety of organisms will be sustained. Support also is included for activities related to integrative and transdisciplinary team-based brain research; data science, infrastructure, tool development for understanding the brain, and specialized training and professional development in multi-disciplinary and international research and large-scale data management and analysis. For more information on UtB, see the NSF-wide Investments Chapter.

- BRAIN Initiative ($19.54 million): As part of UtB, BIO increases support for the BRAIN Initiative, +$1.49 million above the FY 2016 Estimate of $18.05 million. The increase, housed in EF, will support a new solicitation for Neuro-Tech Hubs to be funded in response to the need for a brain observatory, in partnership with MPS and CISE.

BIO Funding for Centers Programs and Facilities

BIO Funding for Centers Programs
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Centers Programs	**$41.42**	**$34.73**	**$31.13**	**-$3.60**	**-10.4%**
Centers for Analysis & Synthesis (DBI)	20.80	18.40	15.80	-2.60	-14.1%
Nanoscale Science & Engineering Centers (DBI)	6.33	6.33	5.33	-1.00	-15.8%
Science & Techology Centers (DBI)	12.66	10.00	10.00	-	-
Science of Learning Centers (DBI)	1.63	-	-	-	N/A

Totals may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- Centers for Analysis and Synthesis: Funding decreases $2.60 million below the FY 2016 Estimate, to a total of $15.80 million. The program will support three centers in FY 2017. The decreased support represents the planned phase-down for two centers: the Plant Science Cyberinfrastructure Collaborative (iPlant) and the National Institute for Mathematical and Biological Synthesis (NIMBioS).
- Nanoscale Science and Engineering Centers (NSEC): Support will be reduced to $5.33 million for the Centers for Environmental Implications of Nanotechnology (CEIN). Forward funding provided in earlier years resulted in a lower funding requirement for FY 2017.
- Science and Technology Centers (STCs): BIO will maintain support for two STCs in FY 2017 for a total of $10.0 million. The Bio/computational Evolution in Action CONsortium (BEACON) remains at a total of $5.0 million. Support is also sustained for the Center for Biology with X-Ray Lasers (X-Fel) at $5.0 million.

BIO Funding for Facilities
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Facilities	**$5.57**	**$49.39**	**$70.35**	**$20.96**	**42.4%**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.45	0.35	0.35	-	-
Cornell High Energy Synchrotron Source (CHESS)	5.00	5.00	5.00	-	-
National Ecological Observatory Network (NEON)	0.12	44.04	65.00	20.96	47.6%

Totals may not add due to rounding.

For detailed information on individual facilities, please see the Facilities chapter.

- BIO's investment for the National Nanotechnology Coordinated Infrastructure (NNCI) will be sustained.
- Cornell High Energy Synchrotron Source (CHESS): BIO support for CHESS will be sustained. CHESS is an important synchrotron facility for studying biological molecules, training beam-line scientists, and providing outreach activities, including a program targeting Native American students.
- Funding for NEON O&M ramps up in FY 2017 to a total of $65.0 million. This represents the final increment from the original three-year O&M award as well as a partial increment for an anticipated one-year extension. This additional year in prototype O&M will allow time for a more complete

understanding of the services and costs proposed and to prepare for a re-competition for a longer term award. The FY 2017 Request amount includes management and technical support, seasonal biological sampling, analytical and archival costs, and domain facilities costs. Funds also will support the calibration and validation laboratories and headquarters functions, such as maintenance of the data center, Observatory monitoring, quality assurance and control, and O&M of the Airborne Observation Platform. In FY 2017, NSF will explore options for operation and maintenance of the full NEON Observatory after construction. For more information on NEON, see the MREFC chapter.

Summary and Funding Profile

In FY 2017, the number of full research grant proposals is projected to increase above the FY 2016 estimated submissions. To accommodate the increase in proposal submissions, BIO will continue with its current proposal submission process: two of BIO's five divisions require a preliminary proposal step and the remaining three divisions have an annual full proposal submission window. Pre-proposals are not counted in the numbers cited in the funding profile below. In FY 2015, BIO received approximately 3,500 pre-proposals. When pre-proposals are included in the funding profile, funding rates are significantly lower, with some program areas below 10 percent. BIO expects to award about 1,600 research grants. Average annual award size will remain flat as BIO moves to limit investment in graduate students on grants; duration will remain constant.

In FY 2017, BIO will invest $31.13 million in centers, accounting for 3.9 percent of the BIO budget.

Operations and maintenance funding for NEON, the only BIO-managed facility, comprises 8.2 percent of BIO's FY 2017 Request.

BIO Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	5,122	5,400	6,200
Number of New Awards	1,382	1,400	1,600
Funding Rate	27%	26%	26%
Statistics for Research Grants:			
Number of Research Grant Proposals	4,303	4,500	5,300
Number of Research Grants	1,033	1,100	1,300
Funding Rate	24%	24%	25%
Median Annualized Award Size	$185,708	$195,000	$195,000
Average Annualized Award Size	$238,573	$250,500	$251,000
Average Award Duration, in years	3.1	3.2	3.2

Program Monitoring and Evaluation

BIO developed a Transparency and Accountability Plan in May 2014. This plan includes several steps that build on prior best practices that have been implemented across the directorate.

- Every program holds a post-panel briefing that includes the program directors, the division director, and the science advisor (if the division has one) to discuss proposed awards and declinations. The briefing includes an analysis of the current portfolio and proposed awards for scientific and demographic information.

- Since FY 2014, the divisions submit narrative annual reports to BIO's Office of the Assistant Director (OAD) that provide information on the division's activities. These are then summarized in the form of a directorate-wide report. In FY 2015, the directorate-wide report included a portfolio analysis that informed the scientific themes presented in BIO's FY 2017 Congressional Budget Request.
- BIO has established a standing BIO Portfolio Analysis Working Group (BPAWG), which is charged with carrying out an annual portfolio analysis at the directorate level, as well as retrospective analyses as needed.
- BIO held two directorate-wide portfolio discussions in FY 2014. The first focused on the emerging scientific gaps, opportunities, and synergies across the directorate. The second discussion focused on the types of tools available and the kind of queries that are possible. The result was a summary of scientific opportunities across divisions and the decision to obtain an enhanced IT tool for better portfolio analysis through text mining. The outputs across FY 2015 – FY 2016 informed the FY 2017 Budget Request.

<u>Committee of Visitors (COV)</u>

- In FY 2015, BIO held one COV in the Division of Environmental Biology (DEB). The COV convened June 17-19 at NSF and reviewed division operations and the programmatic portfolio for FY 2012 to FY 2014. The COV commended the division on the operations and management of a diverse suite of core and special programs that support a broad scientific endeavor. The primary recommendations of the COV centered on implementing additional mechanisms to reduce the variability in proposal reviews written by external experts. The COV also recommended increased staffing to mitigate administrative workloads and continued efforts to increase interactions with the research communities. They strongly endorsed continued internal and external evaluation of the preliminary proposal mechanism.
- In FY 2016 the Division of Biological Infrastructure (DBI) will be holding a COV.
- In FY 2017, BIO is planning to hold COVs for the Division of Molecular and Cellular Biosciences (MCB) and the Division of Integrative Organismal Systems (IOS).

<u>Evaluation</u>

- DEB and IOS are working with the NSF Division of Acquisition and Cooperative Support to award a contract for an external evaluation of the preliminary proposal review mechanism for core programs in the two BIO divisions. The evaluation is expected to address program and research community questions about the outcomes of the preliminary proposal mechanism on the research portfolio and quality of merit review. The contract is expected to be awarded in early CY 2016 and final reporting in early CY 2017.
- DBI will be evaluating its postdoctoral fellowship program across FY 2016 and FY 2017.

<u>Workshops and Reports</u>

- Division of Molecular and Cellular Biosciences:
  - "The Nuts and Bolts of Bioengineered Systems: A workshop on Standards in Synthetic Biology" was held March 2015 in Valencia, Spain and sponsored by MCB, the European Commission (EC), organized by U.S. and European scientists, and attended by representatives from the EC, National Institute of Standards and Technology, Defense Advanced Research Projects Agency, and NSF. Its goal was continued community building and leadership activities around the development of standards for the field of synthetic biology.
  - MCB supported "NIMBioS: National Institute of Mathematical Biosynthesis: A Workshop on Computational Advances in Microbiome Research (CAMR)" in July 2015. It had the goal of bringing together and integrating novel bioinformatics techniques from diverse areas of microbial community research and to identify gaps in computational and statistical techniques not currently addressed in any subfields.

- "Design Principles for Engineering Biology" was held in November 2015 in Virginia, supported by MCB, ENG, and the MPS divisions of Physics (PHY) and Chemistry. This workshop focused on how the convergence of fundamental principles from physics, chemistry, biology, and engineering increasingly provides a quantitative basis for the understanding of biology and enables a rational design of biological systems.
- MCB supports the Computational Modeling in Biology Network (COMBINE) workshops that bring together computer scientists, computational biologists, and engineers to discuss ways to standardize existing computer languages such as System Biology Markup Language (SMBL) for mathematical modeling; the Biological Pathways Exchange Language (BioPaX) for describing pathways; the Systems Biology Graphical Notation (SBGN) for visual representations; and the Synthetic Biology Open Language (SBOL). The major goals of the most recent workshop, held October 2015, were to develop synergistic relationships between systems and synthetic biology researchers and to support a coordinated effort to advocate the use of standards in publications and archival databases.
- MCB and the PGRP in IOS jointly funded two workshops on "The Pathway to a Roadmap: Phytobiomes 2015: Designing a New Paradigm for Crop Improvement. The first workshop was held in Washington, D.C. in June 2015. The second is scheduled for March 6, 2016 in Pacific Grove, CA.
- A workshop co-funded by MCB, ENG, and DEB entitled: "Gene Drives: A Deliberative Workshop to Develop Frameworks for Research and Governance" scheduled for Feb 2016, will address the timely and important issue of second generation genetic engineering technologies being developed with the aim of moving synthetic gene constructs into wild animal populations.
- A workshop on Physics of Wear, Tear, Aging and Failure in Living and Nonliving Systems was supported by MCB along with the Physics of Life Systems program in PHY and was held in May 2015 at Tysons Corner in Virginia. Approximately 25 scientists representing physics, material science, and biology discussed the physical principles and processes underlying aging in living and nonliving system, the similarities and differences between living and nonliving systems and their repair and failure.
- MCB supported an award to the American Society for Biochemistry and Molecular Biology for workshop directed at the career development and mentoring program called Interactive Mentoring Activities for Grantsmanship Enhancement (IMAGE). Developing IMAGE will offer annual mentoring workshops and one-on-one structured mentoring to develop tenable strategies to improve the success rates of under-represented minority faculty in securing funding. The first workshop was held in June 2015 in Washington, D.C.
- MCB supports the SUNY Albany conference, held in June 2015, that serves as an important forum for exchange of new research and ideas among scientists working on diverse aspects of macromolecular structure-function, including RNA localization/structure/catalysis, DNA-protein interactions, DNA damage/repair, DNA nanotechnology, protein folding/design/engineering, optogenetics, among others. A defining feature of this meeting was the emphasis on biophysical and computational approaches to these problems. The meeting has a long history of including young scientists from diverse backgrounds, including 40 percent women speakers and representatives from 20 countries.
- MCB supported the 9th Annual q-bio conference at Virginia Polytechnic Institute in August 2015. This meeting focused on bringing investigators, postdoctoral fellows, and students together to discuss quantitative cell biology as a field that needs to attract experimentalists and modelers to overcome the barriers separating the conventional disciplines that impede significant advances in understanding how cells function. The goal of this effort is to train a new generation of interdisciplinary researchers with the abilities to combine experimental and theoretical approaches to cell biology.

- Division of Integrative Organismal Systems:
  - A workshop entitled "Unpacking the Phenotype (UP): Deciphering Genome to Phenome Relationships - Interdisciplinary Research at the Interface of the Biological and Mathematical Sciences" was held on October 2015. This workshop was jointly supported by IOS, MCB, and the Division of Mathematical Sciences (DMS) in MPS. The workshop brought together mathematicians and biologists to identify opportunities where mathematical modeling approaches would enhance our understanding of multi-scale integration and emergent properties of organisms. A preliminary report was received in December 2015. Among the recommendations are the need to develop mechanisms of support and infrastructure that facilitate collaboration between mathematical and biological scientists. In addition the workshop identified the need for tools that can collect phenotypic spatial and temporal data with the resolution needed for developing robust mathematical models.
  - A BRAIN STEM workshop was held in October 2015 that facilitated discussions among faculty from Primarily Undergraduate Institutions (PUI). The workshop's goal was to identify aspects of the BRAIN Initiative that may be particularly relevant to conducting research and engaging undergraduate researchers at PUIs, identify barriers that could prevent PUI faculty and students from contributing to this effort, and to propose solutions to such impediments. A report from this workshop is pending.
  - A workshop is planned for later in FY 2016 to facilitate dialog among investigators on barriers to integration of multi-scale data sets from the sub-cellular to multi-cellular organisms. This workshop will encourage investigators in the cellular and organismal areas to address barriers and propose solutions to multi-scale integration and the problem of so-called dark data, large data sets that are not easily structured for the computational analyses needed.

- Division of Environmental Biology:
  - The DEB supported workshop "Broadening Participation in Environmental Biology-Exploring What Works" was held in October of 2015. This workshop brought together professors, students, and administrators to discuss "what works" with respect to broadening participation in environmental biology. Prior to the workshop, the organizers interviewed dozens of scientists from underrepresented groups and summarized their stories in a book[1] that is now widely available. Also, a wiki was constructed to foster continued collaboration of participants at the workshop and to encourage new partnerships.
  - The DEB-supported workshop "Improving Inference in Evolutionary Biology and Ecology" was held in November of 2015. At this workshop, editors of practically all major journals of ecology and evolution gathered to discuss how they might collaborate to encourage authors to be more transparent about how conclusions are drawn from data, to encourage publication of all results (regardless of novelty), to replicate studies that have had large impacts on their fields, and to establish standards for data archiving and accessibility.
  - DEB also supported "Infrastructure and ecosystem adaptations in the face of global climate change." This workshop, held on August 15, 2015, was focused on looking forward at the next 100 years of life on Earth and at the same time celebrating the 100th Anniversary of the Ecological Society of America (ESA). It resulted in a special issue of Frontiers in Ecology and the Environment.[2] Specific topics include accelerating rates of sea level rise, long-term droughts, increased flooding, species movements towards northern latitudes and higher elevations, and changes in scientific understanding required for tracking and predicting major changes in ecosystems, in the form of both new statistical analyses and integrated models that cross scales from local populations of organisms to continents.

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[1] ISBN 9780996477536

[2] www.esajournals.org/toc/fron/13/9

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in BIO Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	4,081	4,200	4,400
Other Professionals	1,636	1,700	1,800
Postdoctorates	1,527	1,600	1,700
Graduate Students	2,848	2,900	3,100
Undergraduate Students	4,769	4,900	5,200
Total Number of People	**14,861**	**15,300**	**16,200**

DIVISION OF MOLECULAR AND CELLULAR BIOSCIENCES (MCB) $136,770,000 +$1,240,000 / 0.9%

MCB Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, MCB	**$134.95**	**$135.53**	**$136.77**	**$1.24**	**0.9%**
Research	**132.47**	**133.69**	**134.93**	**1.24**	**0.9%**
CAREER	13.97	14.26	14.39	0.13	0.9%
Education	**2.48**	**1.84**	**1.84**	**-**	**-**

Totals may not add due to rounding.

The FY 2017 Budget Request for MCB is $136.77 million in discretionary funding.

MCB supports fundamental research and related activities that position the community to address a key question in biology, how cells function and change. This focus aligns well with the Directorate's emphasis on the Rules of Life. MCB funded efforts include: studies to explore origins of life; determination of the minimum set of protein and nucleic acid sequences and structures that can sustain life; studies that examine mechanisms of adaptation and homeostasis/robustness of biological systems; identifying the repertoire of gene expression that determines the relationship between genotype and phenotype; and the development of new theoretical concepts that describe cellular decision making.

A key element of BIO's funding priorities include the recognition that acquisition of data alone is insufficient to provide an understanding of rules of life. Therefore MCB prioritizes research that utilize models that are accompanied by experimental systems in which quantitative measures allow theories to be tested, refined, and validated. Committed to fundamental questions in cell and molecular biology, MCB engages traditional approaches but continues to give high priority to interdisciplinary research projects at the interfaces with physical sciences, mathematics, computational sciences, and engineering.

MCB supports systems-level research to uncover emergent biological behaviors that are governed by complex, integrated processes to impart a necessary balance between robustness and plasticity for life on earth. The systems studied range from unicellular to multi-cellular higher life forms, including microbes, microbial communities, fungi, plant systems, and select metazoan model systems. As such MCB is invested in research that focuses on the microbiome as an integral part of our portfolio.

Synthetic biology projects aimed at probing the design principles of biology through the construction of new biological parts, devices and systems, or the re-design of natural systems including regulatory and metabolic networks remain a focus of MCB's efforts. MCB is one of the major supporters of synthetic biology in the Foundation and collaborates with the other BIO divisions to develop and utilize tools that drive systems and synthetic biology. In collaboration with ENG, MCB supports advances in standards in synthetic biology to advance biomanufacturing and development of novel biomaterials that will support the development of a thriving bioeconomy. MCB is a key partner with ENG in developing Engineering Biology as an advanced manufacturing area.

Clean energy technologies have emerged as an important outcome of research in systems and synthetic biology, as projects supported by MCB streamline and scale the metabolic and energetic potential of living organisms such as microbes, fungi, algae and plants to produce non-petroleum based sources of important chemicals/materials, feedstocks, and fuels. Investigations that probe the molecular mechanisms and limits of photosynthesis, including understanding the structure and function of photosynthesis reaction centers are also part of the clean energy portfolio, as are approaches to enhance the efficiency of photosynthesis.

The development of methods, tools, and resources that will be used to tackle major biological questions, such as how non-living systems converge to create emergent properties of living systems and the molecular correlates of environmental changes, continue to be a priority for MCB. Funded research employs a range of experimental approaches – including *in vivo, in vitro* and *in silico* strategies – and a broad spectrum of model and non-model organisms, especially microbes and plants.

Priorities for MCB involve cutting edge foundational research at the interface of traditional disciplines. MCB is committed to training the next generation of scientists and will invest in new training paradigms including programs that provide professional development for trainees outside academia. Additionally, MCB continues to forge international partnerships to support fundamental research in the cellular and molecular sciences and remains committed to these collaborations.

In general, 49 percent of the MCB portfolio is available for new research grants and the remaining 51 percent funds continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>
Research funding for MCB increases $1.24 million, to a total of $134.93 million. Emphases within the research portfolio will:
- Support the Rules of Life emphasis through research at the interface of biology and the quantitative and predictive sciences to yield insights into the fundamental molecular and cellular principles of life that provide the foundation for all of the biological sciences.
- Maintain support for BioMaPS through partnerships with MPS and ENG. This support will foster foundational research activities that employ interdisciplinary, quantitative, and theory-based approaches to understand the function and evolution of living systems.
- Continue efforts to understand how cells make decisions using computer simulations, mathematical models, and quantitative measurements.
- Prioritize fundamental questions on how genes work, how genes are maintained and inherited, and how genes and genomes change using emerging technologies and include identification of novel roles for RNA.
- Invest in synthetic biology aimed at supporting and developing new technologies through a foundational understanding of basic biology (i.e. the support of bacterial immunity research that led to the development of the CRISPR/Cas9 genome editing technology) and the use of the tools of synthetic biology to design new kinds of experiments that enable a greater understanding of the rules of life.
- Contribute to Advanced Manufacturing by supporting research on computational design of biological systems from proteins to organisms to microbial communities that can synthesize fuels, chemicals, and materials, the development of tools and standards in synthetic biology as an approach to the rapid development of biomanufacturing platforms, and the foundational molecular scale research that will produce the next generation of nano-, bio-, and information technologies.
- Invest in research of metabolic systems that will continue to address energy yields and significantly enhance understanding of micro-algal biofuel production.

<u>Education</u>
In FY 2017, MCB's Education investments in Research Experiences for Undergraduates (REU) and Teachers (RET) are maintained at the FY 2016 Estimate of $1.84 million.

Within MCB, new models of training that transitions support of graduate students from research grants to fellowships and/or targeted training programs will be explored. This includes award supplements for graduate students to explore career options, by (for example) participating in internships (in the public and private sector), attending courses that focus on career development, and/or obtaining additional training in specialized areas (e.g. quantitative/computational skills). The end goal is to develop a body of graduate students across the Nation that reflects workforce needs and research priorities.

DIVISION OF INTEGRATIVE ORGANISMAL SYSTEMS (IOS) — $215,400,000 +$1,080,000 / 0.5%

IOS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, IOS	**$215.12**	**$214.32**	**$215.40**	**$1.08**	**0.5%**
Research	**186.29**	**183.49**	**187.97**	**4.48**	**2.4%**
CAREER	13.60	9.20	9.25	0.05	0.5%
Education	**4.47**	**6.63**	**6.63**	**-**	**-**
Infrastructure	**24.36**	**24.20**	**20.80**	**-3.40**	**-14.0%**
Research Resources	24.36	24.20	20.80	-3.40	-14.0%

Totals may not add due to rounding.

The FY 2017 Budget Request for IOS is $215.40 million in discretionary funding.

IOS supports research and education aimed at understanding the structure and function of plants, animals, and microorganisms as complex systems. Activities supported by IOS focus on neural, developmental, physiological, biomechanical, and behavioral processes that characterize organisms, and how they are integrated to result in the dynamic stability of whole organisms. Achieving such a systems-level understanding of organisms is relevant to, and will help advance, the understanding of genomes to phenomes, one of five grand challenges in biology, as well as contribute substantively to understanding the rules of life. IOS seeks to support interdisciplinary approaches and development of new tools. These approaches span computational, mathematical, molecular, cellular, and individual organism levels of inquiry and analysis. IOS-supported research affords new understanding of how a wide diversity of organisms will respond to environmental change to improve our understanding of the reciprocal interactions between the biological and physical-chemical drivers of climate change.

Within IOS, support for neuroscience focuses on the basic functions of the nervous system in response to physical, physiological, and social environments using empirical, theoretical, and computational approaches. Supported research includes comparative and evolutionary approaches to expose common patterns of mechanisms underlying how organisms perceive their physical and social environment. Results of IOS-supported neuroscience will provide the information needed to enable multi-scale integration of these dynamic activities to reveal emergent properties of nervous systems.

The Plant Genome Research Program (PGRP) supports genome-scale research to accelerate discoveries of relevance to basic plant biology, as well as downstream applications of potential societal benefit, such as crop improvement, development of new sources of bio-based clean energy, development of sources of novel bio-based materials, and plant adaptation to global climate change. Genome-enabled technologies developed through PGRP investments are being coupled with synthetic biology approaches to explore engineering of plants as bio-manufacturing and bio-fuel sites that produce useful products, such as oils and clean energy.

In general, 56 percent of the IOS portfolio is available for new research grants and the remaining 44 percent funds continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

Research funding for IOS increases $1.08 million, to a total of $215.40 million. Support within the IOS research portfolio will be used to:

- Collaborate with the National Institutes of Food and Agriculture (NIFA), of the United States Department of Agriculture (USDA), on supporting research in the area of Plant Biotic Interactions (PBI). IOS and NIFA recognized the potential for integration of activities across the spectrum of basic science supported by IOS and the translational agricultural research supported by NIFA in the areas that include plant microbiomes (phytobiomes), plant pathogens, and plant defenses. PBI development began in FY 2015 for a joint IOS/NIFA PBI solicitation in mid FY 2016, with the first awards being made in FY 2017 (estimated IOS share $8.50 million in FY 2017).
- Support the Enabling Discovery through Genomic Tools (EDGE) activity at a level of $10.0 million in FY 2017. Understanding the rules of life will require research on a diversity of organisms, many of which are not sufficiently developed as model organisms to establish cause and effect relationships essential to understanding genomes to phenomes. To address this barrier, the EDGE proposal track was developed in FY 2015, announced in the FY 2016 IOS Core solicitation, with the first awards to be made in FY 2017. Through EDGE, IOS will support research directed towards developing and disseminating tools and methods for enabling emerging model organisms through genomic manipulations that can directly test the relationship of traits (phenomes) with specific genes (genomes).
- Enhance support of clean energy research, via PGRP, by targeting whole genome analysis of plant species valuable for their contributions to bio-fuel development.
- Enhance support for microbiome studies across multiple programs. The Symbiosis, Defense and Self-Recognition (SDS) program supports research in animal-microbiome relationships and the interactions between microbes and protozoa. The PBI program described above will support research on plant-microbe and plant-microbiome (phytobiome) interactions. An increase (+$2.50 million) will be directed towards phytobiome research related to INFEWS.
- Support basic neuroscience research directed towards understanding the development, modification, and activity of the healthy brain during complex natural behaviors. While a significant proportion ($16.10 million of $19.54 million total for BIO) of the activities related to the BRAIN Initiative will be funded through Emerging Frontiers, IOS' investment in neuroscience will support the Understanding the Brain activity, including the BRAIN Initiative, in collaboration with other partners across BIO and NSF. In FY 2016 these activities will focus on opportunities for large-scale data integration, data re-use and synthesis, extending theory, and leveraging the investments in BRAIN EAGERs made in FY 2014 and FY 2015.

Education

- IOS' education investment through the PGRP will continue to provide support ($4.0 million) for the National Plant Genome Initiative (NPGI) Postdoctoral Research Fellowships Program, which is co-sponsored by NSF, the U.S. Department of Energy (DOE), and the U.S. Department of Agriculture (USDA) – Agricultural Research Service (ARS).
- Investments in REU and RET are maintained at $2.14 million and $490,000 respectively.

Infrastructure

Total Research Resource investments decrease $3.40 million to $20.80 million.

- Investments in research resources essential to PGRP, including tools for high-throughput analysis of agriculturally important plant phenotypes under field conditions are maintained.

DIVISION OF ENVIRONMENTAL BIOLOGY (DEB) $145,170,000
+$1,140,000 / 0.8%

DEB Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, DEB	**$143.76**	**$144.03**	**$145.17**	**$1.14**	**0.8%**
Research	**141.62**	**142.01**	**143.15**	**1.14**	**0.8%**
CAREER	6.05	3.84	3.86	0.02	0.5%
Education	**2.14**	**2.02**	**2.02**	**-**	**-**

Totals may not add due to rounding.

The FY 2017 Budget Request for DEB is $145.17 million in discretionary funding.

DEB supports fundamental research to inventory and document all life on earth; to reveal its evolutionary history and current patterns of speciation and extinction; to understand the origins, maintenance, and consequences of biodiversity; to understand the dynamics of integrated, ecological, and evolutionary processes; and to understand feedbacks between natural and human systems.

DEB encourages research that integrates theoretical, modeling, and empirical approaches and promotes synthesis across spatial, temporal, and phylogenetic scales. Scientific foci in DEB address the processes and patterns of evolution, elucidate the integrated dimensions of biodiversity, address the dynamics of species interactions that govern the assembly of functional communities, and determine the flux of energy and materials through ecosystems. DEB includes support for long term research in evolution, ecology, and ecosystem science. Research supported by DEB is enhanced by interactions with the fields of genomics, organismal biology, computer science, geoscience, engineering, and mathematics.

In general, 72 percent of the DEB portfolio is available for new research grants. The remaining 28 percent funds continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

In DEB, total support increases (+$1.14 million, to a total of $143.15 million) for fundamental research on the interactions and feedbacks of ecological and evolutionary processes in the context of changing environmental factors.

- Research priorities will focus on fundamental science related to rules of life. Within DEB, this includes support for development and testing of new theories that transcend the boundaries between ecology and evolution to understand biological phenomena that cannot be explained by either discipline alone.
- Dimensions of Biodiversity, a SEES program, will continue to be supported at $11.0 million. Dynamics of Coupled Natural Human Systems (CNH) program funding will be sustained and leverage additional funding for INFEWS provided in Emerging Frontiers. Research supported by these programs contributes to our understanding of ecosystem services, environmental sustainability, renewal, clean energy, and the nexus of food, energy, and water.

- DEB will contribute to the Administration's clean energy research priority through investments in ecosystem services and biomass production relevant to cellulosic ethanol feedstock production and management, and production of other biofuels.
- With the expected onset of NEON operations, DEB will continue to encourage and support research that uses NEON data and samples to address macro-scale environmental questions, in coordination with funding provided through Emerging Frontiers.
- Consistent with BIO's plan to reorganize its support for graduate students, funding for graduate students on DEB research grants is decreased and will be redirected by BIO to support a new graduate research training program in DBI.

Education

- DEB will maintain FY 2016 support levels for REU ($1.78 million) and RET ($240,000).

DIVISION OF BIOLOGICAL INFRASTRUCTURE (DBI) $135,740,000
-$8,940,000 / -6.2%

DBI Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, DBI	**$144.14**	**$144.68**	**$135.74**	**-$8.94**	**-6.2%**
Research	**47.80**	**42.01**	**46.15**	**4.14**	**9.9%**
CAREER	4.09	5.73	5.81	0.08	1.4%
Centers Funding (total)	41.42	34.73	31.13	-3.60	-10.4%
Centers for Analysis &	20.80	18.40	15.80	-2.60	-14.1%
Nanoscale Science &	6.33	6.33	5.33	-1.00	-15.8%
STC: Center for Microbial	2.66	-	-	-	N/A
STC: BEACON	5.00	5.00	5.00	-	-
STC: Xfel	5.00	5.00	5.00	-	-
Science of Learning Centers	1.63	-	-	-	N/A
Education	**24.28**	**22.47**	**22.89**	**0.42**	**1.9%**
Infrastructure	**72.06**	**80.20**	**66.70**	**-13.50**	**-16.8%**
CHESS	5.00	5.00	5.00	-	-
NNCI	0.35	0.35	0.35	-	-
Research Resources	66.71	74.85	61.35	-13.50	-18.0%

Totals may not add due to rounding.

The FY 2017 Budget Request for DBI is $135.74 million in discretionary funding.

DBI empowers biological discovery by supporting the development and enhancement of biological research resources, human capital, centers, and facilities. In particular, DBI supports the development of, or improvements to: research infrastructure, including instruments, software, and databases; and improvements to biological research collections, living stock collections, and field stations and marine labs. In addition, DBI funds the development of human capital through support of undergraduate, graduate, and postdoctoral research experiences. Support of center, center-like activities, and a few facilities creates opportunities to address targeted but deep biological questions that have major societal impact.

In FY 2017, DBI will assess the effectiveness of current programs towards the evolving needs of the biology community, which have become more complex, diverse, and centered on data storage, access, and analysis. Evaluating current programs, assessing where investments can make a difference in the long term resource needs, and developing a robust STEM pipeline will be a priority. The goals and objectives of many of DBI's longstanding research resource and human resource programs will be reexamined. Emphasis will be placed on evaluation, impact, and scalability, to gauge where support from NSF/BIO makes a difference. Smaller programs with limited long term objectives or scalability will be phased down and potentially terminated. Several programs will be put on a biennial competition schedule during their assessment. BIO expects this assessment to be complete in time to inform the FY 2018 budget.

In general, 31 percent of the DBI portfolio is available for new research grants and 69 percent funds continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

Funding for Research activities in DBI increases $4.14 million, to a total of $46.15 million.

- DBI will continue to assess its research-focused programs for the impacts they are have on research supported across the directorate.
- Support for centers will decrease $3.60 million, to a total of $31.13 million. Support for iPlant and NIMBioS enter their planned phase down. Funding for the STCs SESyNC and BEACON are expected to be renewed at their FY 2016 Estimate levels.
- While the majority of BIO's investment is funded through EF, a significant component of UtB focuses on technologies with connections to activities in DBI that include support for the development of software and databases, as well as student and postdoctoral training in these areas.

Education

- In FY 2017, support for IUSE will continue to be centralized within DBI ($2.50 million) through BIO's RCN-UBE program.
- Funding for the Postdoctoral Research Fellowships in Biology program is maintained at $3.80 million. The Broadening Participation track of this program, funded at $2.50 million, aims to promote the advancement of underrepresented groups in STEM at the postdoctoral level, and will leverage its investment through engagement with other NSF initiatives such as NSF INCLUDES.
- In FY 2017, DBI will contribute $1.40 million to NSF INCLUDES to promote the advancement of underrepresented groups in STEM.
- Support for NSF Research Traineeship increases $490,000, to a total of $2.82 million.
- DBI will maintain support for REU and RET activities at FY 2016 levels ($11.12 million).
- In FY 2017, BIO proposes a new program, BIO Research Training Grant (BIO RTG), as a way to explore alternative mechanisms to support biology graduate students – moving away from the traditional approach of supporting graduate students on research awards to a more directed approach supporting graduate students in one or more areas of strategic national need. The FY 2017 Request includes $6.16 million for DBI to initiate a 3-year pilot.

Infrastructure

Support for biological infrastructure in DBI will decrease $13.50 million, to a level of $66.70 million. This reduction will be accomplished by reducing specific programs associated with research resources and instrumentation as the effectiveness of these programs is assessed with respect to the evolving needs of the biology community.

- Support will continue for cyberinfrastructure necessary for 21st century biology, including the development of tools necessary to address several priority research initiatives including, genotype to phenotype, understanding the brain, and plant genomics.
- DBI will partner with CISE to invest in research that will focus on improving infrastructure for data integration. This is particularly important for integration of different types of data across spatial and temporal scales.
- Emphases within research resources will be related to the new BIO emphasis Rules of Life to include support for multidisciplinary imaging, digitization of biological specimens, and cyberinfrastructure in support of synthetic biology.
- BIO will continue midscale investments for large data-driven science, and, in particular, for CIF21-BioData activities ($8.39 million).
- Two facilities will receive sustained funding: CHESS and NNCI.

DIVISION OF EMERGING FRONTIERS (EF) $157,440,000 +$51,830,000/ 49.1%

EF Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, EF	**$98.22**	**$105.61**	**$157.44**	**$51.83**	**49.1%**
Research	**96.96**	**61.07**	**91.94**	**30.87**	**50.5%**
CAREER	2.83	1.57	1.76	0.19	12.1%
Education	**1.04**	**0.05**	**0.05**	**-**	**-**
Infrastructure	**0.22**	**44.49**	**65.45**	**20.96**	**47.1%**
NEON	0.12	44.04	65.00	20.96	47.6%
NNCI	0.10	-	-	-	N/A
Research Resources	-	0.45	0.45	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for EF is $157.44 million, of which $112.65 million is discretionary funding and $44.79 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

EF identifies, incubates, and supports infrastructure and research areas that transcend scientific disciplines and/or advance the conceptual foundations of biology. Typically, programs and priority areas begin development in EF and then shift to other BIO divisions to become part of the disciplinary knowledge base. Examples include SEES, which is phasing down, and the Advanced Digitization of Biodiversity Collections (ADBC) program which has transitioned into DBI. EF also facilitates the development and implementation of new forms of merit review and mechanisms to support transformative research and stimulate creativity (such as Ideas Labs). These goals are accomplished by promoting cultural change within and across scientific disciplines to increase and strengthen multidisciplinary collaborations, encourage curiosity and exploration through novel mechanisms and investments, and facilitate support of research areas relevant to all of biology by targeted co-funding throughout the directorate.

In FY 2017, the EF portfolio changes as NEON operations and maintenance (O&M) scales up to support infrastructure as construction of the observatory - an NSF MREFC project - nears completion. Funds that were previously centralized in EF to support short-term programs will begin to phase down and transition to support NEON as it becomes fully operational. Given the expected change in managing organizations for NEON, funding for O&M remains in EF until costs are stabilized and predictive; program oversight for the facility has transferred to DBI.

The EF research portfolio will remain diverse in FY 2017 and will evolve, as long standing cross-cutting activities transition to core programs (i.e. BioMaPS and SEES) and new activities are developed such as CNH as a component of INFEWS and the microbiome. In FY 2017, support will continue to focus on MSB and early NEON science, and on Understanding the Brain (UtB) including the BRAIN Initiative.

In general, 71 percent of the EF portfolio is available for new research grants. The remaining 29 percent funds continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

EF Research investments are increased $30.87 million, to a total of $91.94 million in FY 2017.

- Though investments in MSB and early NEON science remain a priority for BIO, support for these programs decreases as funding is redirected to NEON O&M.
- Support for the BRAIN Initiative will increase $1.49 million to $16.10 million and will continue development of a national brain observatory.
- EF will contribute to INFEWS through continued support of CNH and MSB.
- SEES/Dimensions of Biodiversity is reduced to $3.25 million with FY 2017 its final year of support.
- Support for BioMaPS within EF is reduced to $3.25 million but is supplemented by support from MCB and IOS as this cross-cutting activity transitions into core programs.
- Funding for innovation programs continues through investments in new cross-BIO activities, Ideas Labs, and interdisciplinary research.
- Support for early career awardees and research on the rules of life will be enhanced by $44.79 million.

Education

- FY 2017 support for Career Life Balance (CLB) supplements is maintained at the FY 2016 Estimate level.

Infrastructure

- Funding for NEON O&M increases $20.96 million, to a total of $65.0 million. For more detailed information on NEON, see the MREFC chapter.
- Research Resources funding is maintained at the FY 2016 Estimate of $450,000.

DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) $994,800,000 +$58,980,000 / 6.3%

CISE Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Advanced Cyberinfrastructure (ACI)	219.19	222.30	236.31	14.01	6.3%
Computing and Communication Foundations (CCF)	195.69	194.23	206.47	12.24	6.3%
Computer and Network Systems (CNS)	231.45	231.10	245.66	14.56	6.3%
Information and Intelligent Systems (IIS)	194.58	194.90	207.20	12.30	6.3%
Information Technology Research (ITR)	92.07	93.29	99.16	5.87	6.3%
Total, CISE	**$932.98**	**$935.82**	**$994.80**	**$58.98**	**6.3%**

Totals may not add due to rounding.

The FY 2017 Budget Request for CISE is $994.80 million, of which $938.43 million is discretionary funding and $56.37 million is new mandatory funding. The major focus of the mandatory funding is support for CISE's core activities, with special emphasis on early-career investigators.

CISE's request is shaped by a special emphasis on early-career researchers, especially in terms of its new mandatory funding. Early-career investigators not only catalyze the next generation of breakthrough discoveries, but they also embrace novel approaches for accelerating the research enterprise more broadly; today these approaches include significant use of computation and data-intensive techniques, along with the pursuit of increasingly interdisciplinary research that falls at the boundaries of traditional academic disciplines.

Examples of CISE activities related to fostering early-career researchers include:

- Improvement in the overall success rate of high-quality research proposals for core disciplinary programs, including broadening the participation of early-career investigators, women, and underrepresented minorities;
- Emphasis on computational and data-intensive science, well-aligned with CISE's investments in this area;
- Support for research enhancing the robustness and reliability of science and engineering advances; and
- Resources to bridge CISE's core activities further, spanning research and research infrastructure, including interdisciplinary activities with other science and engineering disciplines.

About CISE

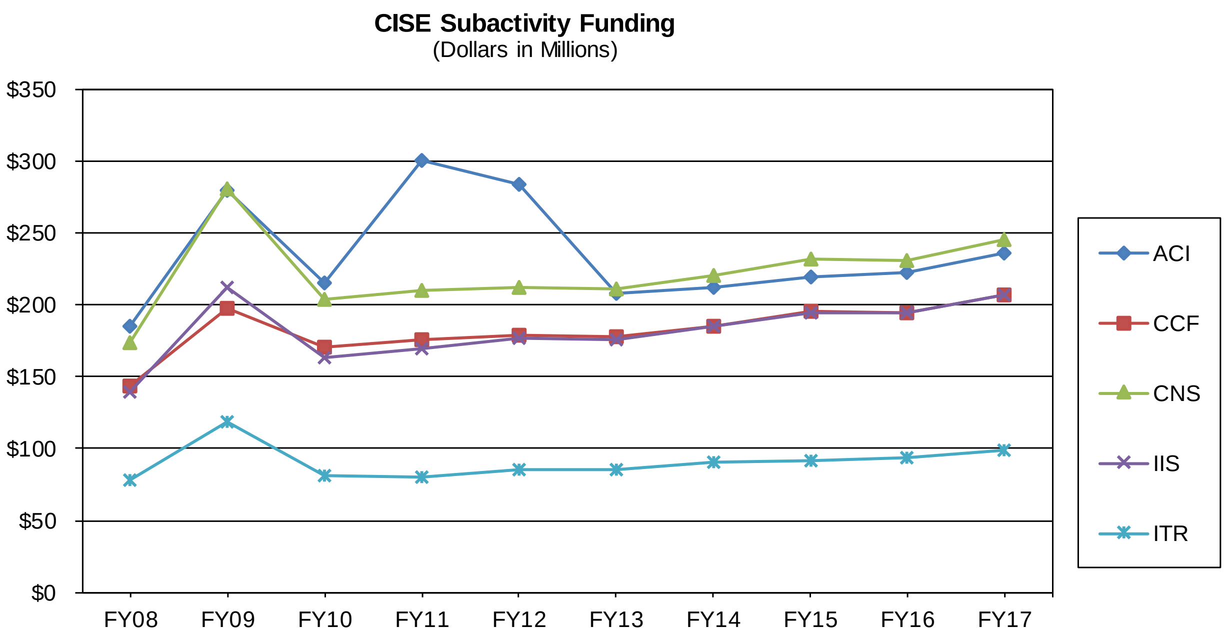
CISE's mission is to promote the progress of computer and information science and engineering research and education, and advance the development and use of cyberinfrastructure across the science and engineering research enterprise; to promote understanding of the principles and uses of advanced computer, communication, and information systems in advancing science and in service to society; and to contribute to universal, transparent, and affordable participation in a knowledge-based society. CISE supports ambitious, long-term research and research infrastructure projects within and across the many sub-fields of computing, as well as cyberinfrastructure for all areas of science and engineering; contributes to the education and training of computing professionals; and, more broadly, informs the preparation of a U.S. workforce with computing and computational competencies essential to success in an increasingly competitive global market.

CISE's FY 2017 Budget Request is shaped by the following NSF-wide priorities: Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS), which includes Advanced Manufacturing, Designing Materials to Revolutionize and Engineer our Future (DMREF), and Smart Systems, which will span a new investment area in Smart and Autonomous Systems (S&AS), along with continuing investments in Cyber-Physical Systems (CPS) and the National Robotics Initiative (NRI); Clean Energy Technology, which includes Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS); Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21), which will begin transitioning to the NSF-wide National Strategic Computing Initiative (NSCI) and Data for Scientific Discovery and Action (D4SDA); Secure and Trustworthy Cyberspace (SaTC); Smart and Connected Communities (S&CC); Risk and Resilience; Understanding the Brain (UtB); Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES); NSF Innovation Corps (I-Corps™); and NSF Research Traineeship (NRT).

CISE continues to provide leadership for the multi-agency Subcommittee on Networking and Information Technology Research and Development (NITRD), which is co-chaired by the CISE Assistant Director. All research, education, and research infrastructure projects supported by CISE enrich the agency's NITRD portfolio. As noted by the President's Council of Advisors on Science and Technology (PCAST) in its *Report to the President and Congress – Ensuring Leadership in Federally Funded Research and Development in Information Technology* (August 2015),[1] advances in Networking and Information Technology (NIT) are key drivers of U.S. economic competitiveness. Essentially all practical applications of information technology (IT) are based on ideas and concepts that emerged from investments in basic computing research, driving discovery and innovation in many other areas. This includes frontiers of scientific research, advanced manufacturing, education and workforce development, health and wellness technologies, sustainability and energy science, transportation, national and homeland security research, and public and private organizational effectiveness and efficiency. These fundamental ideas and concepts have enabled innovative products and applications that now permeate all areas of modern life, positioning NSF and CISE in a central and essential role in improving the Nation's economic outlook and advancing a highly trained, technologically astute workforce.

CISE provides about 82 percent of the federal funding for basic research at academic institutions in the computer sciences.

[1] www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/nitrd_report_aug_2015.pdf



FY 2009 funding reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

The FY 2011 budget for ACI [then the Office of Cyberinfrastructure (OCI)] includes $90.50 million in OCI funds that were obligated in FY 2010, de-obligated in FY 2011, and then re-obligated to other projects in the OCI portfolio. Similarly, the FY 2012 ACI budget includes $71.59 million over the enacted level for OCI due to recoveries of prior-year unpaid OCI obligations that were in turn re-obligated toward other OCI projects in FY 2012.

FY 2017 Summary by Division

- ACI's FY 2017 Budget Request focuses on maintaining its support of research cyberinfrastructure to advance all areas of science and engineering. ACI will begin transitioning its investment from the sunsetting in FY 2017 NSF-wide CIF21 priority area to NSCI and D4SDA, while continuing its investments in programs such as Data Infrastructure Building Blocks (DIBBs), Software Infrastructure for Sustained Innovation (SI^2), EarthCube, and Computational and Data-Enabled Science & Engineering (CDS&E). Together with the Mathematical and Physical Sciences (MPS) directorate, ACI will co-lead the NSF-wide NSCI activity, and will represent NSF in its leadership role across the federal government. ACI's NSCI activities will cultivate an enduring high-performance computing ecosystem, including highly capable, shared research cyberinfrastructure in support of national and Foundation-wide priority areas such as INFEWS and UtB. In coordination with other directorates' research priorities and cyberinfrastructure investments, ACI's D4SDA activities will emphasize both innovative and sustainable data science infrastructure for research communities as well as new approaches to community governance and research data lifecycles in alignment with NSF's *Public Access Plan.*[2] Beyond CIF21, NSCI, and D4SDA, ACI will continue to invest in existing programs in computational science, software, data, networking, and cybersecurity. ACI will also continue to support other cross-disciplinary activities, including transitioning discoveries to practice in SaTC, and fostering resilient critical infrastructure systems through participation in Risk and Resilience. ACI will remain responsible for providing national resources and instruments to facilitate collaborations and greater data sharing across research communities. ACI-supported infrastructure will be used to address some of the most difficult and complex research problems in all areas of science and engineering.

[2] www.nsf.gov/pubs/2015/nsf15052/nsf15052.pdf

- CCF's FY 2017 Budget Request focuses on maintaining support for its core programs as well as NSF-wide investments. CCF will discontinue support for CIF21 as that NSF-wide priority area sunsets, reinvesting some of these funds in NSCI and D4SDA. CCF investments in NSCI will build on past investments in eXploiting Parallelism and Scalability (XPS) to pursue hardware and software research leading to high-performance computing (HPC) systems in the post-Moore's Law era. This includes algorithms and architectures for massive concurrency, energy-efficient computing, and system resilience at extreme scales. CCF investments in D4SDA will pursue foundational techniques to enable computationally efficient storage and processing of big data and more effective query and analysis from heterogeneous data sources. CCF will continue investing in INFEWS, focusing on innovative optimization techniques, algorithms, and software development, as part of its support for Clean Energy Technology; and in UtB, supporting the foundational capabilities necessary to integrate computational models across multiple scales. CCF will also continue to support foundational research in SaTC, including new theories, models, methods, architectures, and tools for increased security, privacy, and trust. As part of the National Nanotechnology Initiative (NNI), CCF will focus on foundational research and nanoscale devices and systems, and will invest in the National Nanotechnology Coordinated Infrastructure (NNCI).

- CNS's FY 2017 Budget Request focuses on maintaining support for its core programs as well as NSF-wide investments. CNS will continue to lead the SaTC program in partnership with the Education and Human Resources (EHR); Engineering (ENG); MPS; and Social, Behavioral, and Economic Sciences (SBE) directorates, as well as the other divisions in CISE. CNS will support CEMMSS through leadership of the CPS program in partnership with the Department of Homeland Security (DHS), Department of Transportation (DOT), National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH), U.S. Department of Agriculture (USDA), ENG, and other CISE divisions. While CNS will discontinue support for CIF21 as that NSF-wide priority area sunsets, the division will reinvest some of these funds in NSCI to advance systems architecture and D4SDA to pursue data-focused research on computer systems. CNS will support the NSF-wide multi-disciplinary activity in S&CC, building on previous investments in Urban Science and US Ignite. These investments will advance fundamental research in advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities. With EHR and the other CISE divisions, CNS will continue to support the STEM + Computing (STEM+C) Partnerships program. Along with EHR, CISE through CNS will also support the Administration's Computer Science (CS) for All initiative, which accelerates NSF's ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation. CNS will continue its support for mid-scale network infrastructure. This includes transitioning NSFFutureCloud prototypes to full-fledged operations; providing programmable testbeds for experimenting with novel cloud architectures; and developing and deploying next-generation software-defined infrastructure, including wireless testbeds.

- IIS's FY 2017 Budget Request focuses on maintaining support for its core programs as well as NSF-wide investments. IIS will increase its investments in cognitive science and neuroscience in support of UtB, building on investments in computational neuroscience and foundational research programs to advance understanding of brain functions. IIS will participate in CEMMSS through leadership of NRI, in partnership with the Department of Defense (DOD), Department of Energy (DOE), NASA, NIH, and USDA, three other NSF directorates (ENG, EHR, and SBE), and other CISE divisions. NRI will accelerate the development and use of robots in the U.S. that work beside or cooperatively with people. In addition, IIS will provide initial support for a new emphasis on S&AS within CEMMSS. S&AS will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. While IIS will discontinue support for CIF21 as the NSF-wide priority area sunsets, the division will reinvest some of these funds in D4SDA and NSCI. IIS investments in D4SDA will focus on the development of novel computational, statistical, and mathematical techniques and technologies for data mining, machine learning, knowledge extraction, visualization, predictive modeling, automated discovery, and decision making, as applied to big data challenges. These investments will also include NSF's continued leadership of the National Big Data R&D Initiative. IIS will invest in INFEWS, supporting novel approaches for large-scale data analysis and management. Additionally, IIS will continue to lead the joint NSF-NIH Smart and Connected Health (SCH) program, in partnership with ENG, SBE, and other CISE divisions. Alongside EHR and ENG, IIS also will continue to lead the Cyberlearning and Future Learning Technologies (CFLT) program, which aims to integrate advances in technology with advances in understanding how people learn, with a focus on online learning environments.

- ITR's FY 2017 Budget Request supports emerging high-priority areas of potentially transformative research. Through continued investments in NSF I-Corps™, ITR will build on foundational research and guide the output of scientific discoveries in the development of technologies, products, and processes that benefit society. ITR will continue to invest in the center-scale Expeditions in Computing program. ITR will invest in multi-disciplinary national and international research networks, aiming to build communities across emerging areas of research and education as well as across geographic boundaries. Working with EHR, ENG, Geological Sciences (GEO), SBE, and other CISE divisions, ITR will invest in S&CC, transitioning prior ITR investments in Urban Science and US Ignite. As part of S&CC, ITR will support fundamental research on advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making, together with the necessary community building efforts, to improve quality of life, health, well-being, and learning in smart and connected communities. ITR will continue its investments in NSF INCLUDES and NRT. ITR will also continue its investments in mid-scale network infrastructure, including transitioning NSFFutureCloud prototypes to full-fledged operations, providing programmable testbeds for experimenting with novel cloud architectures; and developing and deploying next-generation software-defined infrastructure, including wireless testbeds.

Major Investments

CISE Major Investments

(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
CAREER	46.76	39.92	40.46	0.54	1.4%
CEMMSS	89.00	90.98	92.50	1.52	1.7%
Advanced Manufacturing	*41.27*	*43.25*	*41.27*	*-1.98*	*-4.6%*
Clean Energy Technology	21.00	22.57	45.90	23.33	103.4%
CIF21	88.34	84.21	50.00	-34.21	-40.6%
Computer Science for All	-	10.00	10.00	-	-
D4SDA	-	-	19.60	19.60	N/A
INFEWS	-	9.00	6.00	-3.00	-33.3%
National Strategic Computing Initiative	-	-	19.70		
NSF I-Corps™	11.02	11.65	11.65	-	-
NSF INCLUDES	-	1.87	1.78	-	-
NRT[1]	13.38	6.69	7.10	0.41	6.1%
Risk and Resilience	5.50	6.00	6.00	-	-
SaTC	70.56	70.50	70.50	-	-
SEES	13.32	-	-	-	N/A
Smart & Connected Communities/Urban Science	1.00	3.50	16.50	13.00	371.4%
Understanding the Brain	16.50	29.72	23.58	-6.14	-20.7%
BRAIN Initiative	*5.65*	*10.00*	*10.00*	-	-

Major investments may have funding overlap and thus should not be summed.

[1] Commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and were $130,000 in FY 2015. FY 2015 Actual NRT funding includes FY 2014 and FY 2015 NRT awards.

- CAREER: This program invests in the integration of research and education of early-career researchers and contributes to the development of future generations of computer and information scientists and engineers, as well as computational scientists across all areas of science and engineering.

- CEMMSS: CISE, in partnership with BIO, EHR, ENG, and MPS, aims to establish a scientific basis for engineered systems interdependent with the physical world and with humans in the loop, synthesize multi-disciplinary knowledge to model and simulate systems in their full complexity and dynamics, and develop a smart systems technology framework spanning robotic, cyber-physical, and autonomous systems. In FY 2017, CISE will leverage synergistic advances made in earlier years of CEMMSS to place an emphasis on Smart Systems. As part of this emphasis, CISE will continue to lead the CPS and NRI programs, and will also provide initial support for a new investment in S&AS. This investment area will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. This research activity will accelerate the transformation of static systems, processes, and edifices into intelligent, autonomous systems, such as those that can sense, learn, and adapt.

- Advanced Manufacturing: As part of CEMMSS, CISE, in partnership with ENG and MPS, will invest in research that integrates ubiquitous sensors, computational tools, and highly connected cyber-physical systems in smart processing and cyber-manufacturing systems. This investment will enable new functionalities and provide the next generation of products and services in various industries, including higher-quality products with greater efficiency and sustainability produced by the factories of the future. In addition, CISE will continue to support research on co-robots that work alongside or cooperatively with people in manufacturing environments to increase their productivity, performance, and safety as part of its support for NRI.

- Clean Energy Technology: CISE will increase support for foundational research in energy-intelligent computing; the development of new theory, algorithms, and design principles to investigate energy versus computation and communication tradeoffs; and the scalability and sustainability of smart energy production software and hardware. CISE research on clean energy is supported partially via investments in INFEWS, and includes investments in basic research in support of alternative energy and energy efficiency related to batteries, energy storage, and vehicle technologies.

- CIF21: CISE will continue to lead CIF21 while at the same time beginning the transition to new activities under NSCI and D4SDA as the NSF-wide CIF21 priority area begins to sunset. Investments in the Big Data, DIBBs, SI^2, EarthCube, and CDS&E programs will continue. Big Data research will focus on core scientific and technological means of managing, analyzing, visualizing, and extracting useful information from large, distributed, and heterogeneous data sets as well as applications in specific research domains. DIBBs will continue to aim to develop, implement, and support new data cyberinfrastructure to store and manage the diversity, size, and complexity of current and future data sets and streams. To advance new computational infrastructure, SI^2 will seek to advance new paradigms and practices in the development and use of robust, reliable, usable, and sustainable software. Additional information about CISE investments in D4SDA and NSCI is provided below.

- CS for All: Together with EHR, CISE will continue to invest in the CS for All initiative to accelerate NSF's ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation. This funding will support continued prototyping of instructional materials, scalable and sustainable teacher professional development models, approaches to pre-service preparation for CS teachers, and teacher resources, along with research to study their effectiveness.

- D4SDA: CISE will lead the cross-disciplinary D4SDA activity, which will begin enabling 21^{st}-century science, engineering and education to move toward effective use of digital data to advance discovery through activities that promote foundational research in critical techniques and technologies; supporting high-priority, data-intensive science with innovative, reusable data and knowledge infrastructures; enabling and incenting scientific communities to address data governance issues and research data lifecycle issues in alignment with NSF's *Public Access Plan*; and educating the future data-savvy workforce of scientists, engineers, and educators. D4SDA also will develop additional collaborations and partnerships as appropriate.

- INFEWS: CISE will support research on the safety and security of the food-energy-water nexus through investments in new resource management algorithms and architectures; real-time coordination and communications; robust observation, sensing, and inference; large-scale data analysis and management, including modeling and simulation; and optimization of complex systems. As noted below, CISE will support shared cyberinfrastructure for INFEWS through its support for NSCI.

- NSCI: Through ACI, CISE will co-lead the NSF-wide NSCI activity with MPS, and will represent NSF in its leadership role across the federal government. The goal of NSCI is to maximize the benefits of HPC for scientific discovery and economic competitiveness. Under NSCI, CISE will enable advances in HPC systems and maximize their benefits through deep integration of HPC cyberinfrastructure with science and engineering research along a number of key fronts, including increasing coherence between the technology base used for modeling and simulation and that used for data analytics; establishing a viable path forward for HPC systems in the post Moore's Law device and hardware era; and increasing the capacity, capability, and sustainability of an enduring national HPC ecosystem, including addressing foundational algorithms and software, networking technology, accessibility, workflow, and workforce development. CISE's investments will lead to shared cyberinfrastructure for priority areas including INFEWS and UtB.

- NSF I-Corps™: CISE will continue to support I-Corps™ Teams, Sites, and Nodes to further build, utilize, and sustain a national innovation ecosystem that continues to augment the development of technologies, products, and processes that benefit the Nation. CISE's investment will seek to identify NSF-funded researchers who will receive additional support, in the form of entrepreneurial training and mentoring, to accelerate innovation and knowledge transfer that can attract subsequent third-party investment.

- NSF INCLUDES: CISE will participate in NSF INCLUDES, the NSF-wide effort to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or underrepresented in STEM fields.

- NRT: CISE will continue to fund STEM graduate students in interdisciplinary areas of national priority, and to support the development of transformative and scalable models for STEM graduate education.

- Risk and Resilience: In partnership with ENG and SBE, CISE supports the science and engineering necessary to enable advances in large-scale resilient and interdependent infrastructures, particularly in the context of smart and connected communities that are increasingly dependent upon the successful operation of such infrastructures.

- SaTC: NSF continues to align its cybersecurity investments (including investments from EHR, ENG, MPS, and SBE) with the federal cybersecurity R&D strategy through its support of SaTC. This investment area aims to support the research and education that will ensure society's ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. As part of this investment, CISE will continue collaborating with EHR to support cyber-secure workforce development to enable a growing pipeline of researchers and educators, and to develop a citizenry that understands the security and privacy of the digital systems on which society depends. This investment also includes support for the Comprehensive National Cybersecurity Initiative (CNCI) ($48.0 million).[3]

- S&CC: In collaboration with EHR, ENG, GEO, and SBE, CISE will support this NSF-wide multidisciplinary activity, building upon previous CISE investments in US Ignite and Urban Science. As part of this investment, CISE will support a network of regional research hubs that will advance fundamental research on advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making, together with the necessary community building efforts, to improve quality of life, health, well-being, and learning in smart and connected communities. CISE's investment in S&CC will consider the broad context of communities, not just large urban areas, and multiple dimensions and domains, including health and wellness, energy efficiency, transportation, education and learning, and public safety.

- UtB: In collaboration with other NSF directorates and offices, CISE will support core and interdisciplinary projects focused on understanding the brain. In particular, CISE will support projects that develop novel computational approaches for performing multi-scale analysis of physiological, cognitive, and behavioral data; innovative models that accelerate the integration of knowledge across

[3] www.whitehouse.gov/issues/foreign-policy/cybersecurity/national-initiative

scales and across multiple disciplines; and innovative neurotechnologies to monitor and further brain function. This research aims to accelerate the formulation of an integrative, quantitative, and predictive theory of brain function. A portion of CISE funding will continue to support exploration of a National Brain Observatory together with BIO and MPS. As noted above, through NSCI, CISE will support shared cyberinfrastructure for UtB.

CISE Funding for Centers Programs and Facilities

CISE Funding for Centers Programs

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Centers Programs	**$10.00**	**$10.00**	**$10.00**	**-**	**-**
STC: Science of Information (CCF)	5.00	5.00	5.00	-	-
STC: The Center for Brains, Minds and Machines: the Science and the Technology of Intelligence (CCF, IIS, ITR)	5.00	5.00	5.00	-	-

Totals may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- CISE will provide the seventh year of funding for the STC Science of Information at Purdue University. The goal of this center is to develop a new science of information, incorporating common features associated with data/information, such as space, time, structure, semantics, and context, but which are not addressed by earlier mathematical theories, e.g., data obfuscation and hiding techniques. This new science of information will enhance robustness and the principles of redundancy and fault tolerance found in natural systems.
- CISE will provide the fifth year of funding for the STC The Center for Brains, Minds and Machines: the Science and the Technology for Intelligence at MIT. This center has five main research themes: circuits for intelligence; the development of intelligence in children; social intelligence; the integration of visual, motor, language, and social intelligence; and theoretical aspects of intelligence.

CISE Funding for Facilities

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Facilities	**$0.60**	**$0.60**	**$0.60**	**-**	**-**
Nanotechnology Infrastructure Coordinated Program (CCF)	0.60	0.60	0.60	-	-

Totals may not add due to rounding.

For detailed information on individual facilities, please see the Facilities chapter.

Summary and Funding Profile

CISE supports investments in core and interdisciplinary research and education, as well as in computing research infrastructure.

In FY 2017, the number of research grant proposals is expected to increase by approximately 7.0 percent compared to the FY 2016 Estimate. CISE expects to award approximately 1,700 research grants in FY 2017. Average annualized award size and average award duration are expected to remain constant between the FY 2016 Estimate and FY 2017 Estimate.

Funding for research infrastructure represents 17.4 percent of the CISE Request. Most of CISE's research infrastructure support is for High Performance Computing (HPC) (see Appendix A for more information on the HPC portfolio).

CISE Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	8,038	8,600	9,200
Number of New Awards	1,887	1,950	2,100
Funding Rate	23%	23%	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	7,627	8,150	8,700
Number of Research Grants	1,590	1,650	1,750
Funding Rate	21%	20%	20%
Median Annualized Award Size	$160,297	$165,000	$165,000
Average Annualized Award Size	$187,106	$200,000	$200,000
Average Award Duration, in years	2.9	3.0	3.0

Program Monitoring and Evaluation

<u>Committees of Visitors (COV)</u>

- In early FY 2015, CISE convened a Committee of Visitors (COV) to examine and assess the quality of the merit review process across three of its divisions – CCF, CNS, and IIS. The CISE Advisory Committee subsequently accepted the COV report. CISE is not holding any COVs in FY 2016.

<u>Science and Technology Policy Institute (STPI) Reports and Evaluations</u>

- In FY 2012, the Science and Technology Policy Institute (STPI) was tasked to conduct program evaluation feasibility studies for the SaTC and CEMMSS investments. These feasibility studies are providing methods for examining baseline portfolio investments and identifying metrics to measure progress toward program goals. They are a part of a broader effort to develop a plan for impact assessments, particularly of the SaTC investment. The preliminary work to identify baseline evaluation metrics was conducted in FY 2013 – FY 2015, and it is anticipated that further program evaluation analyses will begin once one or more contracts are put into place in FY 2016. In the case of SaTC, yearly program-wide assessments are being presented to NSF senior management.

<u>Computing Education Evaluation</u>

- In addition, evaluation is a key part of CISE's education programs. The STEM+C Partnerships program projects managed by CISE include rigorous research and/or evaluation plans designed to guide project progress and measure project impacts. These plans include descriptions of the instruments and metrics that are to be used in the assessments. CISE has contracted with STPI to conduct an evaluation feasibility study for its STEM+C Partnerships portfolio, and with the Education Development Center, Inc. (EDC) to develop an evaluation instrument for the CS 10K track. The first program evaluation of the CS 10K track is currently being initiated.

Reports

- In 2008, CISE funded the Computer Science and Telecommunications Board (CSTB) within the National Academy of Sciences (NAS) to study the IT innovation ecosystem and to assess the long-term economic impacts of CISE investments. The resulting report, *Assessing the Impacts of Changes in the Information Technology R&D Ecosystem,*[4] published in 2009, includes an in-depth articulation of the creation of almost 20 IT industries since 1965 valued at a minimum of a billion dollars each. To update this study, CISE funded CSTB to identify recent IT industries that have reached the billion-dollar mark; develop a brief report that highlights the updated figures; and summarize results-to-date of IT research, including the nature and successes of U.S. research partnerships among government, industry, and universities, and the economic payoffs of these research investments. The resulting report, *Continuing Innovation in Information Technology*, was published in 2012.[5] A current CSTB study, *Continuing Innovation in Information Technology: A Workshop* (described below), is employing this report's framework.
- In FY 2012, a CSTB study, *The Future of Computing Performance: Game Over or Next Level?,*[6] together with a white paper from the CISE-funded Computing Community Consortium (CCC), *21st Century Computer Architecture,*[7] outlined the need for advances in computer architecture research which led to the development of the XPS program that was initiated in FY 2013.
- In FY 2013, the CCC collected community white papers articulating the potential needs and payoff for additional investments in mid-scale infrastructure for computing research;[8] this led to the development of the NSFFutureCloud program started in FY 2014.
- In FY 2014 through FY 2015, the CCC led several additional community visioning efforts that have the potential to influence the development of CISE programs in FY 2017:
    - *Computing Visions 2025:*[9] sought to inspire the computing community to envision future trends and opportunities in computing research. Two workshops were held under this initiative: *Interacting with Computers All Around Us*, and *The New Making Renaissance: Programmable Matter and Things.*
    - *A New Age of Computing and the Brain*: sought to bring together computer and information scientists and brain researchers to explore opportunities and connections at the intersection of computer and information science and brain science. The CCC has published a workshop report summarizing the key findings, which stands to influence CISE's and NSF's UtB investment.[10]
    - *Toward a Science of Autonomy for Physical Systems:*[11] sought to offer a series of white papers framing the challenges and opportunities associated with a future of autonomous physical systems across a range of domains including healthcare, transportation, and disaster response. These white papers have the potential to influence CISE's S&AS investment.
- CISE also funded four CSTB studies that are currently ongoing and have the potential to influence the development of CISE programs in FY 2017:
    - *Continuing Innovation in Information Technology: A Workshop:*[12] conducted a public workshop that highlights additional examples of the impacts of computing research using the framework established in the "tiretracks" figure published in CSTB's 2012 report *Continuing Innovation in*

[4] www.nap.edu/catalog.php?record_id=12174
[5] www.nap.edu/catalog.php?record_id=13427
[6] www.nap.edu/openbook.php?record_id=12980
[7] http://cra.org/ccc/docs/init/21stcenturyarchitecturewhitepaper.pdf
[8] http://cra.org/ccc/visioning/visioning-activities/mid-scale-infrastructure-investments-for-computing-research
[9] http://cra.org/ccc/visioning/computing-visions-2025/
[10] http://cra.org/ccc/wp-content/uploads/sites/2/2014/12/BRAIN-Report.pdf
[11] http://cra.org/ccc/resources/ccc-led-whitepapers/#toward-a-science-of-autonomy-for-physical-systems
[12] http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_086055

Information Technology and explore further uses of the figure and framework.

- *A Primer on Cybersecurity: Leveraging Two Decades of National Academies Work:*[13] is examining what is known about effective technical and nontechnical approaches, the state of the art and open challenges, why relatively little progress has been made in cybersecurity despite the recommendations of many reports from the Academies and elsewhere, and potential policy responses.
- *Toward 21st-Century Cyber-Physical Systems Education:*[14] is completing a study on the current and future needs in education for cyber-physical systems (CPS), and articulating a vision for a 21st-century CPS-capable U.S. workforce.
- *Future Directions for NSF Advanced Computing Infrastructure to support U.S. Science in 2017-2020:* is examining anticipated priorities and associated tradeoffs for advanced computing in support of NSF-sponsored science and engineering research. An interim report was published in FY 2014,[15] and a final report is anticipated in FY 2016.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in CISE Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	7,302	7,400	7,800
Other Professionals	1,278	1,300	1,400
Postdoctoral Associates	498	500	500
Graduate Students	6,423	6,500	6,900
Undergraduate Students	2,367	2,400	2,600
Total Number of People	**17,868**	**18,100**	**19,200**

[13] http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_073130
[14] http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_084351
[15] www.nap.edu/catalog/18972/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-and-engineering-in-2017-2020

DIVISION OF ADVANCED CYBERINFRASTRUCTURE (ACI) $236,310,000
+$14,010,000 / 6.3%

ACI Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, ACI	**$219.19**	**$222.30**	**$236.31**	**$14.01**	**6.3%**
Research	**93.62**	**93.30**	**107.31**	**14.01**	**15.0%**
CAREER	1.52	2.00	2.00	-	-
Education	**9.12**	**5.20**	**5.20**	**-**	**-**
Infrastructure	**116.45**	**123.80**	**123.80**	**-**	**-**
Networking and Computational Resources Infrastructure and Services	116.45	123.80	123.80	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for ACI is $236.31 million, of which $222.92 million is discretionary funding and $13.39 million is new mandatory funding. The mandatory funding is within the research line in the above table.

ACI partners with other CISE divisions and NSF directorates and offices to support the advancement of science and engineering research and education by exploring, developing, creating, and supporting secure, advanced, and global cyberinfrastructure (CI). This includes the acquisition, integration, coordination, and operations associated with data, networking, computation, and software, and the development of computational and data-enabled science and engineering tools and expertise. ACI focuses on the development of these resources and capabilities, as well as on the expertise to conduct next-generation science and engineering, in order to address complex and multidisciplinary discovery, prediction, and innovation. ACI provides computational support to more than 8,000 faculty and researchers, and supports international activities in networking, software, data, and computation, including connectivity to major international resources and scientific instruments. ACI also fosters relationships among academic research infrastructure groups, as well as among other federal agencies and international research funding agencies with shared scientific priorities to promote collaborative research cyberinfrastructure.

At present, about 36 percent of the ACI portfolio is available for new grants and 64 percent is available for continuing grants.

Approximately 60 percent of ACI's budget is used to support individuals and small groups of researchers in pilot, prototype, and innovative multidisciplinary projects. The remaining 40 percent of the budget goes toward the support of larger cyberinfrastructure consortia, including the eXtreme Digital (XD) shared services program, the Blue Waters Petascale Computing program, and the Innovative High-Performance Computing (HPC) program. Collectively these larger-scale initiatives complement and connect both smaller NSF-supported as well as university-supported cyberinfrastructure as part of a larger, integrated, national cyberinfrastructure ecosystem.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- ACI will continue to support early-career researchers through investments in the CAREER program ($2.0 million).
- ACI will begin to transition its investment from the sunsetting NSF-wide CIF21 investment (-$12.71 to $50.0 million) to NSCI ($7.70 million) and D4SDA ($4.70 million). Together with MPS, ACI will co-lead the NSF-wide NSCI activity, and will represent NSF in its leadership role across the federal government. ACI's NSCI research activities in FY 2017 will emphasize the creation of novel scientific software architectures that are resilient, reusable, and enduring yet agile to accelerate computational discovery in national research priority areas. ACI research activities in NSCI are complemented by computational infrastructure activities, as noted below. In coordination with other directorates' research priorities and cyberinfrastructure investments, ACI's D4SDA activities will emphasize both innovative and sustainable data science infrastructure for research communities as well as new approaches to community governance and research data lifecycles in alignment with NSF's *Public Access Plan*.
- ACI will continue its investment in Risk and Resilience ($2.50 million), enabling advances in large-scale resilient, secure, and interoperable research cyberinfrastructure.
- ACI will continue its support of SaTC ($3.0 million), leading the Transition to Practice (TTP) Option, which explores new approaches for adopting advances in security, including emphasizing interagency and cross-sector collaborations.
- ACI will continue its research support for INFEWS ($500,000), enabling the development of robust and resilient software for multidisciplinary research. This investment is part of ACI's support for Clean Energy Technology ($5.0 million).

Education

- ACI will continue to support the NSF Research Traineeship program ($2.50 million) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training for research areas of national priority and in alignment with NSCI objectives.
- ACI will maintain its investments in STEM+C Partnerships ($500,000), which seek to enhance computational competencies for students and teachers.
- ACI will maintain support for Research Experiences for Undergraduates (REU) sites and supplements ($1.20 million).

Infrastructure

- ACI's support (-$1.30 million to $91.0 million) in Advanced Computational Infrastructure will retain its alignment with research priorities and its focus on a highly interoperable research infrastructure (see Appendix A for more information on the HPC portfolio).
- ACI will make an initial investment in NSCI-specific activities ($7.50 million), transitioning INFEWS-specific (-$2.50 million) and UtB-specific cyberinfrastructure investments (-$5.0 million) to shared cyberinfrastructure in NSCI. A portion of the UtB-specific cyberinfrastructure investment ($1.0 million) will be retained to support exploration of a National Brain Observatory in collaboration with BIO and MPS.

DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS (CCF) — $206,470,000 / +$12,240,000 / 6.3%

CCF Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, CCF	**$195.69**	**$194.23**	**$206.47**	**$12.24**	**6.3%**
Research	**182.24**	**184.53**	**196.61**	**12.08**	**6.5%**
CAREER	16.90	12.18	12.35	0.17	1.4%
Centers Funding (total)	8.00	8.00	8.00	-	-
STC: The Center for Science of Information	5.00	5.00	5.00	-	-
STC: The Center for Brains, Minds and Machines: the Science and the Technology of Intelligence	3.00	3.00	3.00	-	-
Education	**12.85**	**9.10**	**9.26**	**0.16**	**1.8%**
Infrastructure	**0.60**	**0.60**	**0.60**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.60	0.60	0.60	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for CCF is $206.47 million, of which $194.77 million is discretionary funding and $11.70 million is new mandatory funding. The mandatory funding is within the research line in the above table.

CCF supports research and education activities that explore the foundations and limits of computation, communication, and information; advance algorithmic knowledge for research areas both within and outside computer science; and advance software, hardware, and computer system design. CCF's research investments support advances in the design and analysis of algorithms; computational complexity; theoretical and experimental studies of algorithms and their resource requirements; and formal models of computation. These research investments include approaches for parallel, distributed, and heterogeneous multi-core machines. CCF invests in research addressing the theoretical underpinnings and enabling technologies for information acquisition, transmission, and processing in communication and information networks, such as sensor, wireless, multimedia, and biological networks. CCF investments advance the design, verification, evaluation, and utilization of computing hardware and software through new theories and tools that focus on performance, correctness, usability, dependability, reliability, and scalability. CCF also invests in research that explores the potential impact of emerging technologies on computation and communication, including nanotechnology, biotechnology, and quantum devices and systems.

In general, 74 percent of the CCF portfolio is available for new research grants and 26 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CCF will continue to support early-career researchers through increased investments in the CAREER program (+$170,000 to $12.35 million).

- CCF will provide initial support ($1.0 million) for a new emphasis on S&AS within the NSF-wide CEMMSS priority area. CCF investments in S&AS will focus on sensing and navigation for intelligent autonomous physical systems, with an emphasis on novel techniques for signal processing, formal verification, and end-user programming. CCF will also continue its investments in NRI ($3.0 million) and CPS (-$1.0 million to $4.50 million).
- CCF will discontinue support for CIF21 (-$8.25 million) as the NSF-wide priority sunsets, reinvesting some of these funds in NSCI ($3.0 million) and D4SDA ($4.70 million). CCF investments in NSCI will pursue hardware and software research leading to HPC systems in the post-Moore's Law era, including algorithms and architectures for massive concurrency, energy-efficient computing, and system resilience at extreme scales. CCF investments in D4SDA will pursue foundational techniques that enable computationally efficient storage and processing of big data and more effective query and analysis from heterogeneous data sources.
- CCF will invest ($1.50 million) in S&CC. As part of this investment, CCF will support a network of regional research hubs that will advance fundamental research on processing high volumes of sensor data as well as novel advances in control, automation, and decision making in systems affecting quality of life, health, well-being, and learning in smart and connected communities.
- CCF will continue to participate in INFEWS (-$250,000 to $2.25 million), focusing on foundational research on novel approaches for large-scale data analysis and management, innovative optimization techniques, and development of new algorithms and software. This investment is part of CCF's support for Clean Energy Technology ($16.40 million).
- CCF will continue to participate in UtB (-$300,000 to $8.35 million) through investments in core and crosscutting research, including integrating computational models across multiple scales for improved understanding of the theory of brain function.
- CCF will continue its investment in SaTC ($14.25 million), supporting research on theories, models, algorithms, architectures, programming languages and tools for increased security, privacy and trust, as well as in new cryptographic approaches for hardware assurance.
- CCF will continue to invest in SCH (-$1.0 million to $2.0 million), supporting signal processing and control research with application to devices and sensors for person-centered health and wellbeing. CCF will decrease SCH investments as it transitions funds to S&CC to support research on improving health and well-being in smart and connected communities.
- CCF will continue to support two STCs, the Center for Science for Information at Purdue University ($5.0 million) and The Center for Brains, Minds, and Machines: The Science and the Technology of Intelligence at MIT ($3.0 million). The total CISE investment in the MIT Center ($5.0 million) is shared with the IIS and ITR divisions.

Education

- CCF will continue to support the NSF Research Traineeship program (+$160,000 to $1.16 million) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.
- CCF will maintain its investments in STEM+C Partnerships ($4.0 million), which seek to enhance computational competencies for students and teachers.
- CCF will maintain support for REU sites and supplements ($3.25 million).

Infrastructure

- CCF will fund the National Nanotechnology Coordinated Infrastructure (NNCI) ($600,000), supported primarily by ENG.

DIVISION OF COMPUTER AND NETWORK SYSTEMS (CNS) $245,660,000
+$14,560,000 / 6.3%

CNS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, CNS	**$231.45**	**$231.10**	**$245.66**	**$14.56**	**6.3%**
Research	**184.02**	**184.33**	**197.67**	**13.34**	**7.2%**
CAREER	8.03	11.83	12.00	0.17	1.4%
Education	**18.14**	**16.77**	**15.77**	**-1.00**	**-6.0%**
Infrastructure	**29.29**	**30.00**	**32.22**	**2.22**	**7.4%**
Research Resources	29.29	30.00	32.22	2.22	7.4%

Totals may not add due to rounding.

The FY 2017 Budget Request for CNS is $245.66 million, of which $231.74 million is discretionary funding and $13.92 million is new mandatory funding. The mandatory funding is within the research line in the above table.

CNS supports research and education activities that advance understanding of the fundamental properties of computer systems and networks; explore new ways to better use existing computer systems and networks; and develop novel paradigms, abstractions, and tools for designing, analyzing, and building next-generation computer systems and networks that are robust, secure, and trustworthy. CNS investments include, but are not limited to, cyber-physical, embedded, cloud computing, wearable, and “smart dust” systems. CNS investments in fundamental networking research create new insights into the dynamics of complex networks, and explore new architectures for future-generation networks and services. CNS provides scientific leadership in cybersecurity, supporting research and education activities that will ensure society’s ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. CNS also plays a leadership role in coordinating CISE investments in research infrastructure resources for the computer and information science and engineering research community, and in the development of the computing workforce of the future.

In general, 68 percent of the CNS portfolio is available for new research grants and 32 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CNS will continue to support early-career researchers through increased investments in the CAREER program (+$170,000 to $12.0 million).
- CNS will provide initial support ($6.0 million) for a new emphasis on S&AS, within the NSF-wide CEMMSS priority area, focusing on fundamental science and engineering addressing programmable, reliable, and secure intelligent autonomous systems. Additionally, in partnership with five other federal agencies (DHS, DOT, NASA, NIH, and USDA), ENG, and other CISE divisions, CNS will continue to lead the CPS program (-$3.50 million to $19.50 million), supporting foundational interdisciplinary research and education in adaptive, scalable, resilient, safe, secure, and usable cyber-physical systems.

CNS will also continue to invest in NRI (-$1.50 million to $3.0 million).
- CNS will invest in S&CC ($6.0 million), building upon previous investments in Urban Science (-$2.50 million) and US Ignite (-$5.0 million). As part of its S&CC investment, CNS will support a network of regional research hubs that will advance fundamental research in advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities.
- CNS will discontinue support for CIF21 (-$3.75 million) as the NSF-wide priority area sunsets, reinvesting some of these funds in NSCI ($2.0 million) and D4SDA ($1.0 million). CNS investments in NSCI will support foundational research leading to HPC systems in the post-Moore's Law era, including performance and scalability of parallel computing, cross-layer, and systems architecture research. CNS investments in D4SDA will support data-focused research on computer systems, and associated data and knowledge testbeds and pilot research infrastructures.
- In partnership with EHR, ENG, MPS, SBE, and other CISE divisions, CNS will continue to lead SaTC ($44.30 million). Through SaTC, CNS will invest in areas of current critical importance such as network and cloud security, cybereconomics, and the science of security and privacy, alongside education and workforce issues. Furthermore, through SaTC, CNS will include support for experimental testbeds to enable cybersecurity researchers to experiment in realistic environments.
- CNS will continue its investment in Risk and Resilience ($3.50 million), supporting the science and engineering needed to enable advances in large-scale resilient and interdependent infrastructures.
- CNS will continue its investment in INFEWS (-$250,000 to $2.20 million), focusing on foundational systems research in sensing, control, automation, and optimization of the complex systems underlying the nexus of food, energy, and water systems. This investment is part of CNS's support for Clean Energy Technology ($19.50 million).
- CNS will continue its investment in UtB (-$200,000 to $1.54 million), supporting research developing improved systems for computation and analysis of physiological, cognitive, and behavioral data.

Education
- CNS will continue to invest in NSF INCLUDES ($1.0 million) to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or underrepresented in STEM.
- CNS will maintain its investments in STEM+C Partnerships, which seek to enhance computational competencies for all students ($4.0 million). This program will enlarge the pool of K-14 students and teachers who develop and practice computational competencies in a variety of contexts. This includes partial support for the CS for All initiative.
- CNS will maintain support for REU sites and supplements ($4.48 million).
- CNS will continue to support the NSF Research Traineeship program ($490,000) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.
- In partnership with ENG and EHR, and under the IUSE investment framework, CNS will continue to invest in IUSE/Professional Formation of Engineers: REvolutionizing engineering and computer science Departments (IUSE:RED) ($2.0 million), with a particular focus on responding to increased enrollments in computer science.

Infrastructure
- Through the CISE Research Infrastructure (CRI) program ($18.0 million), CNS will continue to support acquisition, enhancement, community access, and operation of state-of-the-art computing research infrastructure enabling high-quality computing research and education.
- CNS will continue its support for the development of world-class, mid-scale research infrastructure (+$2.22 million to $14.22 million). CNS will transition NSFFutureCloud prototypes to full-fledged operations, providing programmable testbeds for experimenting with novel cloud architectures; and

develop and deploy next-generation software-defined infrastructure, including wireless testbeds that enable research on topics ranging from radio access networks to spectrum sharing and adaptability.

DIVISION OF INFORMATION AND INTELLIGENT SYSTEMS (IIS) $207,200,000 +$12,300,000 / 6.3%

IIS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, IIS	**$194.58**	**$194.90**	**$207.20**	**$12.30**	**6.3%**
Research	**184.07**	**185.60**	**197.65**	**12.05**	**6.5%**
CAREER	20.03	13.91	14.11	0.20	1.4%
Centers Funding (total)	1.00	1.00	1.00	-	-
STC: The Center for Brains, Minds and Machines: the Science and the Technology of Intelligence	1.00	1.00	1.00	-	-
Education	**10.51**	**9.30**	**9.55**	**0.25**	**2.7%**

Totals may not add due to rounding.

The FY 2017 Budget Request for IIS is $207.20 million, of which $195.46 million is discretionary funding and $11.74 million is new mandatory funding. The mandatory funding is within the research line in the above table.

IIS supports research and education to develop and apply new information technology to enhance the capabilities of people and machines to create, discover, and reason by advancing their ability to represent, collect, store, organize, visualize, and communicate data and information; to develop new knowledge to support people in the design and use of IT; and to advance knowledge about how computational systems can perform tasks autonomously, robustly, and flexibly. IIS research investments support the exploration of novel theories and innovative technologies that advance understanding of the complex and increasingly coupled relationships between people and computing, and promise to enhance quality of life. Investments in information integration and informatics focus on the processes and technologies involved in creating, managing, visualizing, and fusing diverse data, information, and knowledge from disparate and uncoordinated sources within a changing landscape of computing platforms, from personal devices to globally-distributed networks. IIS also invests in research on artificial intelligence, computer vision, natural language processing, robotics, machine learning, computational neuroscience, cognitive science, and areas leading to the computational understanding and modeling of intelligence in complex, realistic contexts. These investments aim to revolutionize understanding of brain functions.

In general, 70 percent of the IIS portfolio is available for new research grants and 30 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- IIS will continue to support early-career researchers through increased investments in the CAREER program (+$200,000 to $14.11 million).
- IIS will provide initial support ($9.50 million) for a new emphasis on S&AS within the NSF-wide CEMMSS priority area. S&AS will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. Additionally, in partnership with five other federal agencies (DOD, DOE, NASA,

NIH, and USDA), three other NSF directorates (ENG, SBE, and EHR), and other CISE divisions, IIS will continue to lead the NRI program (-$3.50 million to $9.50 million). NRI focuses on human-centered research in developing service robots; this requires significant advances in human-robot interaction, advanced sensing and control, integrated problem-solving architectures and decision algorithms; and safe and soft structures. IIS will also continue its investments in CPS (-$3.50 million to $1.0 million).

- IIS will discontinue support for CIF21 (-$9.50 million) as the NSF-wide priority area sunsets, and will reinvest some of these funds in D4SDA ($8.20 million) and NSCI ($500,000). IIS investments in D4SDA will focus on the development of novel computational, statistical, and mathematical techniques and technologies for data mining, machine learning, knowledge extraction, visualization, predictive modeling, automated discovery, and decision making, as applied to big data challenges. These investments will include NSF's continued leadership of the National Big Data R&D Initiative. IIS investments in NSCI will pursue the development of computational techniques and technologies for data-intensive computing, data and image analytics, and distributed machine learning.
- IIS will invest ($5.70 million) in S&CC. As part of this investment, IIS will support a network of regional research hubs that will advance fundamental research on technologies integrating data-intensive computing; physical sensors/devices; and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities.
- IIS will continue its investments in UtB (-$640,000 to $12.69 million) by supporting core and crosscutting research in developing novel computational tools for performing multi-scale analysis of physiological, cognitive, and behavioral data, and innovative models that accelerate the integration of knowledge across scales and across multiple disciplines. This research aims to accelerate the formulation of an integrative, quantitative, and predictive theory of brain function.
- In partnership with six NIH institutes, ENG, SBE, and other CISE divisions, IIS will continue to lead the SCH program (-$3.0 million to $6.0 million). IIS will pursue improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies. IIS will decrease SCH investments as the division transitions funds for health- and wellness- related research to S&CC and S&AS.
- IIS will continue to lead the Cyberlearning and Future Learning Technologies (CFLT) program with EHR, ENG and other CISE divisions (-$4.50 million to $5.25 million). This activity will integrate advances in technology with advances in the ways people learn; resolve how to use technology more effectively for promoting learning; and design new technologies for integration in learning environments and evaluate their use. IIS will decrease CFLT investments as the division transitions funds for learning-related research to S&CC and S&AS.
- IIS will continue its investment in SaTC ($8.95 million), supporting research in cybersecurity and privacy, with an emphasis on data science, usability, socio-technical, and human-centered approaches.
- IIS will continue to participate in INFEWS ($1.05 million), focusing on novel approaches for large-scale data analysis, real-time data analytics, and artificial intelligence. This investment is part of IIS's support for Clean Energy Technology ($5.0 million).
- IIS will continue to provide support for STC The Center for Brains, Minds and Machines: The Science and the Technology of Intelligence at MIT ($1.0 million) along with the CCF and ITR divisions.

Education

- IIS will continue to support the NSF Research Traineeship program (+$250,000 to $750,000) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.
- IIS will maintain its investments in STEM+C Partnerships ($4.0 million), which seek to enhance computational competencies for students and teachers.
- IIS will maintain support for REU sites and supplements ($3.95 million).

DIVISION OF INFORMATION TECHNOLOGY RESEARCH (ITR) $99,160,000 +$5,870,000 / 6.3%

ITR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, ITR	**$92.07**	**$93.29**	**$99.16**	**$5.87**	**6.3%**
Research	**76.01**	**76.47**	**79.72**	**3.25**	**4.3%**
CAREER	0.28	-	-	-	N/A
Centers Funding (total)	1.00	1.00	1.00	-	-
STC: The Center for Brains, Minds and Machines	1.00	1.00	1.00	-	-
Education	**2.95**	**3.32**	**3.23**	**-0.09**	**-2.7%**
Infrastructure	**13.12**	**13.50**	**16.21**	**2.71**	**20.1%**
Research Resources	13.12	13.50	16.21	2.71	20.1%

Totals may not add due to rounding.

The FY 2017 Budget Request for ITR is $99.16 million, of which $93.54 million is discretionary funding and $5.62 million is new mandatory funding. The mandatory funding is within the research line in the above table.

ITR provides support for transformative explorations in computer and information science and engineering research, infrastructure, and related education activities, emphasizing the funding of high-risk, multi-investigator projects.

In general, 45 percent of the ITR portfolio is available for new grants and 55 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- ITR will invest in NSF I-Corps™ ($11.65 million) to provide NSF-funded researchers with additional support – in the form of entrepreneurial training and mentoring – to accelerate innovation and transfer of knowledge from lab to practice. As part of this investment, ITR will support I-Corps™ Sites and Nodes to build, utilize, and sustain further a national innovation ecosystem that continues to augment the development of technologies, products, and processes.
- In collaboration with ENG, CISE will maintain support for innovative partnerships and collaborations between academia and industry, in part through the Industry/University Cooperative Research Centers (I/UCRC) program, which will continue to support centers that partner university research efforts with industry ($8.0 million).
- ITR will maintain its investments in the center-scale Expeditions in Computing program ($12.0 million). This program will continue to support projects with transformative research agendas that promise to accelerate discovery at the frontiers of computer and information science and engineering.
- ITR will invest in multi-disciplinary research networks ($2.0 million), including support for the Science Across Virtual Institutes (SAVI) activity. These national as well as international research networks

will provide opportunities to develop collaborations in areas of emerging interest to computer and information science and engineering.

- ITR will continue to provide support for emerging and urgent high-priority areas of potentially transformative research through various award mechanisms, such as EArly-concept Grants for Exploratory Research (EAGERs) and Grants for Rapid Response Research (RAPIDs), and through co-funding of awards with other NSF directorates to pursue important emerging areas.
- ITR will maintain support ($1.0 million) for the STC Center for Brains, Minds and Machines: The Science and the Technology of Intelligence at MIT along with the CCF and IIS divisions.
- ITR will invest in S&CC ($3.30 million), building upon previous investments in Urban Science (-$1.0 million) and US Ignite (-$5.0 million). As part of its S&CC investment, ITR will support a network of regional research hubs that will advance fundamental research on advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making, together with the necessary community building efforts, to improve quality of life, health, well-being, and learning in smart and connected communities.

Education

- ITR will continue to invest in NSF INCLUDES (-$90,000 to $780,000) to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or underrepresented in STEM.
- ITR will continue to support the NSF Research Traineeship program ($2.20 million) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.

Infrastructure

- ITR will maintain support for the development of world-class, mid-scale research infrastructure (+$2.71 million to $16.21 million). ITR will transition NSFFutureCloud prototypes to full-fledged operations, providing programmable testbeds for experimenting with novel cloud architectures; and develop and deploy next-generation software-defined infrastructure, including wireless testbeds that enable research on topics ranging from radio access networks to spectrum sharing and adaptability.

APPENDIX A – HIGH-PERFORMANCE COMPUTING PORTFOLIO

High Performance Computing Funding
(Dollars in Millions)

	Total of Prior Years	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Petascale Computing	$355.02	$42.75	$14.90	$40.50
Innovative HPC Program	241.17	18.50	50.90	26.50
Extreme Digital (XD)	397.26	13.40	26.50	24.00
Total	**$993.45**	**$74.65**	**$92.30**	**$91.00**

Totals may not add due to rounding.

NSF has been a leader in the use of High-Performance Computing (HPC) to advance discovery for almost four decades. As a result of continuous rapid changes in computing and related technologies, coupled with the exponential growth and complexity of data for the science, engineering, and education enterprise, NSF developed a vision and strategy for Advanced Computing Infrastructure (ACI), which expands NSF's leadership role in science and engineering. This coordinated NSF-wide strategy, entitled *Cyberinfrastructure for 21st Century Science and Engineering: Advanced Computing Infrastructure*,[16] seeks to position and support the entire spectrum of NSF-funded communities at the cutting edge of advanced computing technologies, hardware, and software, and aims to promote a more complementary, comprehensive, and balanced portfolio of advanced computing infrastructure and programs for research and education. The strategy enables multidisciplinary computational and data-enabled science and engineering that supports all science, engineering, and education communities. This shift is consistent with the recommendations of recent reviews of the NITRD program by the President's Council of Advisors on Science and Technology (PCAST).[17,18]

The overall HPC strategy and program portfolio receives guidance and input from a number of stakeholder groups. This includes the Advisory Committee for Cyberinfrastructure (ACCI) and its task forces; the NSF cross-directorate Cyberinfrastructure Council (CIC), which includes Assistant Directors (ADs) and Office Directors; the various NSF research directorates and offices; and the NSF-wide Cyberinfrastructure Coordination and Leadership Group (CLG). Additionally, in 2013, ACI supported the initiation of a two-year National Academy of Sciences (NAS) study to further inform the implementation of its HPC strategy in the 2017 to 2020 timeframe. NAS published an interim report in November 2014, and NSF expects to receive the final report by February 2016.[19]

NSF's current HPC portfolio comprises three broad areas of investment that complement large but more discipline-specific investments by other NSF directorates, mission-specific investments by other agencies, and cumulatively massive but individually smaller investments of academic institutions at the regional and campus level:

- **Petascale Computing.** This first investment category focuses on the unique services and resources to advance the most computationally intensive scientific and engineering research, as provided by Blue Waters.

[16] www.nsf.gov/pubs/2012/nsf12051/nsf12051.pdf
[17] *Designing a Digital Future: Federally Funded Research and Development Networking and Information Technology,* President's Council of Advisors on Science and Technology, January 2013.
[18] www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/nitrd_report_aug_2015.pdf
[19] www.nap.edu/catalog/18972/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-and-engineering-in-2017-2020

- **Innovative HPC.** The second investment category focuses on a national portfolio of diverse and innovative resources at large scale, exemplified by Stampede. While the Blue Waters system is targeted to a smaller number of researchers delivering sustained petascale performance on the very largest computational problems across a variety of disciplines, the Innovative HPC systems provide greater community reach through diversity in the types and scale of resources: each system is capable of supporting hundreds to thousands of researchers (over the course of a year) conducting leading-edge science and engineering; and the portfolio of systems supported is intended to be technically diverse, reflecting changing and growing use of computation in research and education.
- **Extreme Digital (XD).** The third investment category focuses on an accompanying set of collaborative and shared services available to the entire HPC community, and is exemplified by the Extreme Science and Engineering Discovery Environment (XSEDE) project. The constellation of general-purpose and specialized HPC resources across the nation described in the first two investment categories is complemented by a unique set of collaborative services under XSEDE, including for coordination, coherency and interoperability, education, outreach and allocation of these diverse computational resources to nearly 2,000 unique scientific projects annually.

As the scientific computing landscape rapidly grows and evolves, and as computing technologies change, NSF's investments in HPC must necessarily evolve rapidly and dynamically to meet current research needs and to support new research opportunities across science and engineering. In 2014, NSF participated in an OSTP-led multiagency activity, which resulted in an Executive Order initiating the National Strategic Computing Initiative (NSCI).[20] NSF, together with the Department of Defense (DOD) and Department of Energy (DOE), is co-leading this initiative. NSF's focus is on scientific discovery advances, notably an emphasis on a holistic approach to the Nation's science and engineering computational infrastructure including new approaches to highly capable, reusable, and agile scientific software, as well as learning and workforce development. Among the anticipated activities will be a follow-on investment to Blue Waters with attributes to be determined based on scientific and engineering priorities. As part of NSCI, NSF participated in a joint Request for Information with NIH and DOE on *Science Drivers Requiring Capable Exascale Computing*.[21] Approximately 250 responses were received, and these are now being analyzed internally and will also inform NSF's support of HPC and its participation in NSCI in FY 2017 and beyond.

PETASCALE COMPUTING PROGRAM – BLUE WATERS

Description

The National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC) provides computational resources for researchers to tackle much larger and more complex research challenges than previously possible. This capability was accomplished by acquiring, deploying, and operating a petascale leadership-class, high-performance system known as Blue Waters. Blue Waters is one of the most powerful supercomputers in the world, and is the fastest supercomputer on a university campus. It is important to note that this investment complements the DOE Office of Science's program on computing hardware, which provides peak petascale performance as measured by the Top500 list.[22] In contrast, Blue Waters provides sustained petascale performance on a range of scientific applications.

The Blue Waters project includes education and outreach programs that target pre-college, undergraduate, graduate, and post-graduate students. The Virtual School of Computational Science and Engineering was established as part of the project, creating courses and certificate programs focusing on petascale computing and petascale-enabled science and engineering. The Blue Waters project also has sponsored workshops,

[20] www.whitehouse.gov/the-press-office/2015/07/29/executive-order-creating-national-strategic-computing-initiative
[21] www.nsf.gov/pubs/2016/nsf16008/nsf16008.pdf
[22] www.top500.org/

conferences, summer schools, and seminars.

The Blue Waters project includes an annual series of workshops targeted at the developers of simulation packages and aspiring application developers. The project also includes two industrial partnership activities. The Industry Partners in Petascale Engagement (IPIPE) program provides industrial partners with a first look at the technological and scientific developments that flow from the petascale program. The Independent Software Vendor Application Scalability Forum promotes collaborations among consortium members, independent software vendors, and the industrial end-user community.

The broader impacts of this award include provisioning unique cyberinfrastructure for research and education; extensive efforts accelerating education and training in the use of high-performance computation in science; training in petascale computing techniques; promoting an exchange of information between academia and industry about the applications of petascale computing; and broadening participation in computational science through NCSA's Girls Engaged in Mathematics and Science (GEMS) program. The GEMS program is designed to encourage middle-school girls to consider mathematics- and science-oriented careers.

Current Status

The Blue Waters system was operational in December 2012, and the archival storage availability came online in March 2013. It is operated by NCSA and includes the Great Lakes Consortium for Petascale Computing (GLCPC) as a partner. Support for the first six months of operations was provided in the acquisition and deployment award. Support for the remaining operational phase, from FY 2014 through mid-FY 2018, was awarded to UIUC in FY 2013.

The Blue Waters education and outreach projects are ongoing. They comprise components on pre-college, undergraduate, graduate, and post-graduate education; training workshops; and outreach. Annual "Petascale Workshops" provide scientists and engineers with the knowledge and expertise needed to develop applications for Blue Waters and other petascale computers. In addition, annual extreme scale workshops are held jointly with the XSEDE project. The Blue Waters team also hosts summer workshops and has created and offered courses through the Virtual School of Computational Science and Engineering mentioned above. Partnering with the Shodor Foundation, a nonprofit national resource for computational science education, the Blue Waters project offers undergraduate petascale course materials and internships. In 2014, Blue Waters Graduate Fellowships were announced for ten students from nine institutions in eight different states across the U.S. Six Ph.D. students were selected for Blue Waters Graduate Fellowships in 2015.

Science and engineering research and education activities enabled by Blue Waters

Blue Waters is enabling investigators across the country to conduct innovative research demanding petascale capabilities. In particular, research teams have been allocated time on Blue Waters through the Petascale Computing Resource Allocations (PRAC) program. These allocations began in 2013 with approximately 30 teams awarded time on Blue Waters, with a second round of awards to 14 teams made in 2014 and a third round of awards to 14 teams made in 2015. Over time, approximately 185 requests for usage have been submitted across a wide spectrum of research areas. The next PRAC call is anticipated in April 2016. The research topics awarded time allocations on Blue Waters include: complex biological behavior in fluctuating environments; the electronic properties of strongly correlated systems; the properties of hydrogen and hydrogen-helium mixtures in astrophysically relevant conditions; the electronic and magnetic structures of transition metal compounds; the molecular dynamics responsible for the properties of liquid water; and the propagation of seismic energy through a detailed structural model of Southern California together with the prediction of ground motion and modeling of the response of buildings and other structures. Other allocations address testing hypotheses about the role of cloud processes and ocean mesoscale eddy mixing in the dynamics of climate and improving climate models; the formation of the first galaxies; turbulent stellar hydrodynamics; binary black hole and neutron star systems as sources of gamma ray bursts; and other intense radiation phenomena, contagion, and particle physics. Additionally, in collaboration with the National Geospatial-Intelligence Agency (NGA) and the University of Minnesota's Polar Geospatial Center (PGC), Blue Waters is being used to produce elevation models for all landmasses north of the 60^{th} parallel – a significant contribution in support of the President's Executive Order calling for Enhancing Coordination of National Efforts in the Artic.[23]

Over 50 scientific papers were published each year in 2013 and 2014 based on research conducted using Blue Waters allocations. In 2015, the number of scientific papers published exceeded 80. Furthermore, the project has issued annual calls for educational allocations directly involving students, including the Blue Waters Undergraduate Student Internship Program (22 students in 2015) and the Blue Waters Graduate Fellowship Program (six awards in 2015). After more than two years in service, Blue Waters has supported over 150 science projects (spanning research, education, industry outreach, etc.), and more than 1,400 scientists and engineers from over 163 institutions in 33 states.

Management and Oversight

NSF Structure: CISE/ACI program staff and staff from the Division of Acquisition and Cooperative Support (DACS) oversee the Blue Waters project. These NSF staff members receive strategic advice from the CIC. Advice from the Office of General Counsel (OGC) is sought, as necessary.

External Structure: The primary sub-awardee, Cray, is responsible for maintenance of the hardware, system software, and main program development tools. Other sub-awardees worked on extreme-scale parallel algorithm and method development, the engagement of applications groups, scalable performance tools, undergraduate training, and broadening the participation of underrepresented groups in HPC. During the operational phase, the Science and Engineering Team Advisory Committee (SETAC), whose composition and roles were reviewed and approved by an external panel in July 2013, advise the project team. This Committee is composed of representatives from research teams with Blue Waters allocations, industry scientists pursuing petascale applications, and the GLCPC.

Risks: The NSB receives updates on any major change in risk assessment, which is reviewed annually by an external panel. Risks identified during the operational phase of the project include system security, power costs, and performance/reliability/usability due to large system scale.

Reviews: An external panel of experts, selected by NSF, periodically reviews the progress of the project, including project management, risk management, hardware and software performance, usability and reliability, and the provision of advanced user support to research groups receiving resource allocations on the Blue Waters system. One of the important roles of this external review panel is to analyze the awardee's assessments of intellectual merit and broader impacts based on the use of the system for research and education. To date, these external reviews have been conducted in February 2008, April 2008, October 2008, April 2009, July 2009, December 2009, April 2010, September 2010, December 2010, February 2011, May 2011, September 2011, March 2012, August 2012, December 2012, July 2013, December 2014, and December 2015. An update to the National Science Board was provided in February 2015.

INNOVATIVE HPC PROGRAM

Description

Innovative HPC systems provide petascale peak performance. The key difference from the DOE Office of Science support for computing hardware is that over the course of a year each system is capable of supporting hundreds to thousands of researchers conducting leading-edge science and engineering. The

[23] www.whitehouse.gov/the-press-office/2015/01/21/executive-order-enhancing-coordination-national-efforts-arctic

portfolio of systems supported by the Innovative HPC program is intended to be technically diverse, reflecting changing and growing use of computation in both the research and education process.

There is a direct relationship between the Innovative HPC and XD programs. Several systems are currently serving as allocable resources within XD. Innovative HPC awards are generally made as two parts: an acquisition component with associated funding, and an operations and maintenance component with associated funding. Some Innovative HPC awards do not separate these components because of the experimental nature of the systems. When an award is made, funding is provided to the institution, which issues sub-awards to vendors for acquisitions as necessary. Once the system has passed the acceptance process, vendors receive final payment for the system. After the system has been tested fully, it becomes an XD resource and the institution becomes an XD resource provider. At this point, the award funding may be used for operations and maintenance of the system.

Beginning with the FY 2011 solicitation, *High Performance System Acquisition: Enhancing the Petascale Computing Environment for Science and Engineering*, a more sustained approach to the largest HPC services was initiated. This solicitation was based on feedback from the scientific and engineering community, providing a longer time horizon for funding HPC providers in recognition of the value and time required for building and retaining staff skilled in interdisciplinary computational science. Thus, an eight- to ten-year award horizon is envisioned for a core HPC provider. This timeline begins with an acquisition award, which allows for the possibility of a renewal acquisition award four years after the original award. In addition to the acquisition awards, accompanying operations and maintenance (O&M) awards are planned.

Current Status

Machines that are currently operational in the Innovative HPC program include Stampede at the Texas Advanced Computing Center (TACC), Gordon at the San Diego Supercomputer Center (SDSC), Comet (SDSC), Darter at the National Institute for Computational Sciences (NICS), and Wrangler (TACC).

- NSF support for Gordon and Darter is scheduled to end in FY 2016. Gordon was an early adopter of Flash-based large memory nodes to explore data-intensive science and engineering in areas such as understanding practices and patterns in high-frequency trading on Wall Street; improving the accuracy of predicting high-impact extreme weather events; and examining high-resolution hydrology scenarios for planning more resilient water management in South Florida. The use of Flash-based large memory nodes has become more common and is currently available in other systems. Darter has been especially effective for large-scale scientific applications that are only tractable with low latency for random memory access and/or high memory bandwidth. This is typical of certain large, high-resolution scientific simulations, for example, high-resolution turbulence and large eddy simulations (LES). Thus, fields such as astrophysics, high-energy physics, and fluid mechanics comprised the portfolio of science enabled by Darter. Elimination of Darter's support will partially be offset by new resources planned for deployment in FY 2016.

- The Stampede project at the University of Texas at Austin delivered a new system for allocation of NSF XD cyberinfrastructure services in January 2013, and is scheduled to operate until January 2017. The resource and accompanying services target science and engineering researchers using both advanced computational methods and emerging data-intensive approaches. The system has boosted XD resources to nearly twice their previous capacity, and has provided researchers with early access to Intel Many Integrated Core (MIC) processors, which were accepted in August 2013.

- Wrangler came online in FY 2015 at the University of Texas at Austin. Wrangler is the most powerful data analysis system allocated in XD, with 10 petabytes (PB) of replicated, secure, high-performance data storage. In its final configuration, it consists of 3,000 embedded processing cores for data analysis;

120 Intel Haswell-based servers for data access and embedded analytics; and a large-scale flash storage tier for analytics, providing users with up to a half-PB of usable storage, supported with available bandwidth of up to one terabyte per second (TB/s) and 200 million Input/Output Operations Per Second (IOPS). The system provides flexible support for a wide range of software stacks, including Hadoop and relational data. These are integrated with Globus Online services for rapid and reliable data transfer and sharing. Support for ongoing Wrangler operations and maintenance continues through FY 2019.

- Comet also came online in FY 2015 at the University of California, San Diego. It is designed to be part of an emerging cyberinfrastructure for the "long tail of science," which encompasses the idea that a large number of modestly-sized, computationally-based research projects still represent a tremendous amount of research and scientific impact. Notably, as a resource that is responsive to the "long tail of science," Comet is particularly well suited for science gateway use. Its heterogeneous configuration supports not only complex simulations, but also advanced analytics and visualization of outputs.

Two new resources are now being acquired, developed and deployed through awards made following the FY 2014 solicitation, *High Performance Computing System Acquisition: Continuing the Building of a More Inclusive Computing Environment for Science and Engineering*. These two new resources continue to broaden the spectrum of the program by exploring new and creative approaches to delivering innovative computational resources to an increasingly diverse community and portfolio of scientific research and education projects. A key goal is to include new communities with needs that are different than the more traditional HPC users, but that would benefit from advanced computational capabilities at the national level. This solicitation resulted in two awards that are scheduled to be deployed in FY 2016:

- Bridges, to be deployed at the Pittsburgh Supercomputing Center, will provide an innovative and groundbreaking HPC and data-analytic system that will integrate advanced memory technologies and data-intensive workflows to lower the barrier of entry to HPC and to increase the scientific output of a large community of scientific and engineering researchers who have not traditionally used HPC resources. Bridges will extend HPC's impact to minority-serving institutions and EPSCoR states, raising the level of computational awareness at four-year colleges, and promote computational thinking in high schools.

- Jetstream, to be deployed at Indiana University, will be a new type of data analysis and computational resource for the open science and engineering research community that will be used interactively to conduct research anytime, anywhere. It complements the current NSF-funded computational resources portfolio by bringing online a cloud-based system incorporating the best elements of commercial cloud computing resources with some of the best software in existence for solving important scientific problems. Jetstream enables new modes of sharing computations and data, allowing for increased scientific reproducibility and enabling many U.S. researchers and engineers to make new discoveries that are important to understanding the world around us, improving the quality of life of American citizens, and promoting America's competitive standing.

For both Bridges and Jetstream, support for ongoing operations and maintenance will begin in FY 2016 and continue through FY 2019. They represent additional capabilities that are intended to appeal to the larger and increasingly diverse demand for national-scale resources.

Science and engineering research and education activities enabled by Innovative HPC

The complete spectrum of scientific research can leverage Innovative HPC resources. This includes climate and weather modeling, economics, cosmology and astrophysics, geosciences, physics, chemistry, biology and medicine, earthquake engineering, and mechanical engineering.

Innovative HPC is enabling world-leading transformative advances in science and engineering research, in the integration of research and education, and in broadening participation in science and engineering by underrepresented groups. These advances are enabled by providing researchers and educators with usable access to computational resources beyond those typically available on most campuses, together with the interfaces, consulting support, and training necessary to facilitate their use.

Through the unifying XD framework and services, Innovative HPC enables researchers to manipulate extremely large amounts of digital information from simulation, sensors, and experiments, and add needed capabilities in remote visualization, an increasingly important analysis tool for modern science and engineering.

Outreach and training is critical in order to reduce barriers for the research and education community to use HPC systems, and the program is engaging research universities and foundations to achieve this goal. Innovative HPC incorporates new computational technologies and new approaches to software and data management, together with the expertise to enable researchers and students to complement theory and experiment with an equal emphasis in computation.

Management and Oversight

NSF Structure: CISE/ACI's program directors provide direct oversight during both acquisition and operations phases. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors. The program directors also hold biweekly teleconferences with the awardees.

External Structure: Each Innovative HPC award is managed under a cooperative agreement that includes the management structure, milestones, spending authorization levels, and review schedule; and each awardee is responsible for the satisfactory completion of milestones prior to the raising of the spending authorization. Each project also has a detailed management plan in place.

Risks: Any activity of this nature, and at this scale, comes with a certain element of risk. The review process, conducted prior to an award, analyzes the risks as presented in the proposal and identifies any additional risk that should be considered. The awards are experimental in nature; therefore, they encompass high-risk, high-reward scenarios. The award process requires that risks be identified and analyzed, and that a mitigation plan be created and followed. One of the activities of the periodic NSF external reviews, conducted by an external panel of experts, is to revisit and assess the risk situation and make recommendations as deemed necessary. Risks that are no longer applicable are retired. New risks may be added, or the degree of risk promoted or demoted as necessary, all of which is documented in a risk register. Typically, project risks are reduced substantially subsequent to deployment. Thus, pacing of acquisitions and deployments allows balance in overall portfolio risk for Innovative HPC.

Reviews: Semi-annual reviews typically are performed during the acquisition phase. Annual reviews, conducted by an external panel of expert reviewers, are performed during the operational phase of each project. CISE/ACI program directors manage these annual reviews. The reviewers' backgrounds include scientific research, project management, large-scale systems acquisitions and operations, along with familiarity with projects funded by NSF as well as other federal agencies.

EXTREME DIGITAL (XD) PROGRAM

Description

The XD program adds value to the Innovative HPC program by coordinating the resources, providing advanced assistance to the user community, and broadening participation. The vision is to create and sustain an advanced, nationally-distributed, open cyberinfrastructure consisting of shared user and management services, supercomputing, storage, analysis, visualization systems, data services, and science gateways connected by high-bandwidth networks, integrated by coordinated policies and operations, and supported by computing and technology experts.

XD enables and supports leading-edge scientific discovery and promotes science and technology education. The program encourages innovation in the design and implementation of an effective, efficient, increasingly virtualized approach to the provision of high-end digital services, while ensuring that the cyberinfrastructure continues to deliver high-quality access for the many researchers and educators who use it in their work.

XD shared services consist of several interrelated parts: allocation of resources to computational and data research projects; advanced user assistance; training, education and outreach; architecture and operation of an integrated digital services infrastructure; metrics services; and overall coordination. The XD Metrics Service (XMS), formerly the Technology Audit Service (TAS), is a separate award. All other services constitute the XSEDE project. These elements are designed and implemented in a way that is tied clearly to the requirements of the science and engineering research community, using a flexible methodology that permits the architecture to evolve in response to changing community needs and that presents the individual user with a common environment regardless of where the resources or researchers are located.

Current Status

Two awards are currently active within the XD program: XSEDE and XMS. A third award, the Technology Insertion Service (TIS), ended in FY 2016, and in response to external review, NSF determined that TIS would no longer be supported. The XMS award was made in FY 2015 to the State University of New York at Buffalo, renewing the previous TAS project. This award provides metrics services allowing measurement of key operational data for both resources and services. The larger XSEDE award was made to the University of Illinois at Urbana-Champaign in July 2011. The four additional major partners in XSEDE are the University of Texas at Austin (TACC), University of Pittsburgh (Pittsburgh Supercomputer Center), University of Tennessee at Knoxville (National Center for Computational Science), and University of California, San Diego (SDSC). NSF held annual reviews of XSEDE in June 2012, June 2013, and September 2014.

Science and engineering research and education activities enabled by XD

XD services enable transformative advances in science and engineering research, in the integration of research and education, and in broadening participation in science and engineering to underrepresented groups. This is accomplished by providing researchers and educators with coherent and highly usable access to extreme-scale digital resources beyond those typically available on most campuses, together with the interfaces, consulting, advanced user support, and training necessary to facilitate their use.

XD provides HPC services; enables researchers to manipulate extremely large amounts of digital information from simulations, sensors, and experiments; and adds needed capabilities in remote visualization, an increasingly important analysis tool for modern science and engineering.

XD's XSEDE project is developing tools and services that not only link users to national facilities, but also enable scientific collaborations of geographically distributed teams. In doing so, it facilitates access to digital resources and experimental testbeds within and across university campuses, as well as government laboratories.

The XSEDE project includes outreach and training critical to reducing the barriers to the use of advanced digital systems by the research and education communities. The project incorporates new ideas and technologies to enable researchers and students to move transparently between local and national resources, substantially lowering the barriers to effective use of cyberinfrastructure and promoting enhanced productivity.

Management and Oversight

NSF Structure: CISE/ACI program directors oversee the XD program. XSEDE has an external advisory board, a user board, and a service provider forum to ensure that all stakeholders can provide project input. CISE/ACI oversight of the XSEDE project includes participation in weekly teleconferences with senior XSEDE personnel and in quarterly project-wide staff meetings. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors.

External Structure: Each XD award is managed under a cooperative agreement that includes the management structure, milestones, spending levels over time, and review schedule; and each awardee is responsible for satisfactory completion of milestones prior to processing of grant increments. Each project also has a detailed management plan in place.

Risk: While XD is operational in nature, the virtual organizations of the XSEDE project and the services of the XD projects are innovative and thus bear inherent risks. The projects maintain risk registers that are reviewed periodically by external panels and by the cognizant program directors. Identified risks and planned actions are reported to and reviewed with the program directors.

Reviews: External panels of expert reviewers conduct annual reviews (for XSEDE) and mid-project reviews (for XMS). CISE/ACI program directors manage these annual reviews. The reviewers' backgrounds include scientific research, project management, operations of HPC centers, and familiarity with projects funded by NSF as well as other federal agencies.

DIRECTORATE FOR ENGINEERING (ENG) $1,002,730,000
+$86,540,000 / 9.4%

ENG Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Chemical, Bioengineering, Environmental, and Transport Systems (CBET)	$180.40	$183.82	$198.42	$14.60	7.9%
Civil, Mechanical, and Manufacturing Innovation (CMMI)	225.55	216.39	233.92	17.53	8.1%
Electrical, Communications, and Cyber Systems (ECCS)	118.97	113.95	122.77	8.82	7.7%
Engineering Education and Centers (EEC)	117.95	107.61	120.32	12.71	11.8%
Industrial Innovation and Partnerships (IIP)	227.26	239.93	268.90	28.97	12.1%
Emerging Frontiers and Multidisciplinary Activities (EFMA)	53.41	54.49	58.40	3.91	7.2%
Total, ENG	**$923.53**	**$916.19**	**$1,002.73**	**$86.54**	**9.4%**

Totals may not add due to rounding.

FY 2015 Actual includes $21.18 million in carryover from the prior fiscal year as follows: CMMI - $11.32 million, ECCS - $6.48 million, EEC - $200,000, and EFMA - $3.19 million.

The FY 2017 Budget Request for ENG is $1,002.73 million, of which $946.41 million is discretionary funding and $56.32 million is new mandatory funding. The major focus of the mandatory funding is support for core activities, with special emphasis on supporting early-career investigators, advancing engineering research through effective use of data and cyberinfrastructure, and investing in disruptive technologies to enable post-Moore’s Law computing systems. Examples of activities include, but are not limited to:

- Expand support for early-career investigators and stimulate breakthrough research ideas, encourage risk taking and innovative thinking among young investigators.
- Support engineering research directions that combine mainstream engineering fields for transformative use of stored and real-time streaming data to advance discovery and stimulate data-intensive fundamental engineering research through ENG core programs. Examples include: simulation and modeling for nanosystems science and engineering; understanding of interdependent and interconnected infrastructure systems; understanding of energy landscapes of chemical reactions; modeling and simulation of biological functions and complexity across multiple length scales; novel system science and engineering that are better suited for a data rich world; and mitigation of, preparedness for, response to, and recovery from multi-hazard disasters by leveraging data from diverse sources.
- Support fundamental engineering research in materials, devices, and systems architecture that will potentially establish a viable path forward for future advanced computing systems in the post-Moore’s Law era, thus enabling future possibilities for the advancement of computing.

About ENG

Fundamental research supported by ENG, combined with the creativity of well-educated engineers and the resources of state-of-the-art facilities, has resulted in many important discoveries. These discoveries have fueled exciting technological innovations – including, for example, nanotechnology-enabled consumer, industrial, and health care products and manufacturing; novel laser-based tools for brain research and neurological diseases; devices and systems for communications and computing; and Internet-enabled smart advanced manufacturing systems and supply chains – that in turn have stimulated economic growth and are improving the quality of life for all Americans.

In FY 2017, ENG's approach aims to bring about new breakthroughs for national priorities and grand challenges by (1) implementing key Administration and NSF-wide investment priorities, and (2) supporting core programs in frontier engineering research.

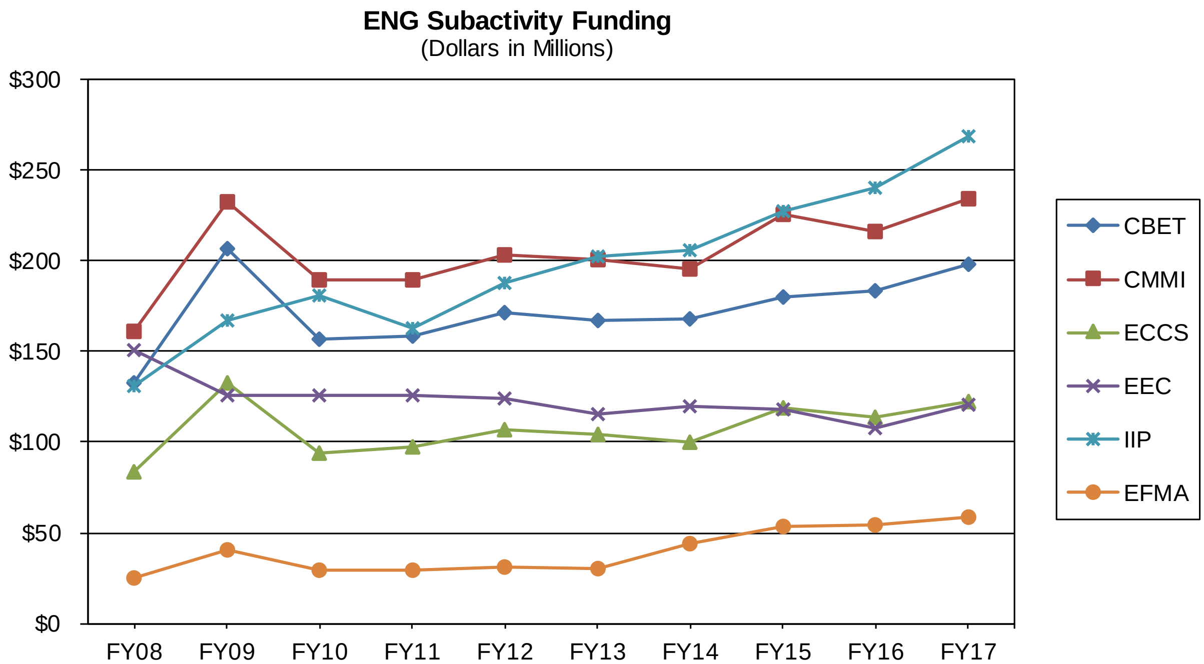
The directorate will continue to invest throughout its core programs in emerging and frontier basic research areas, including, for example, advanced materials and manufacturing, systems science and engineering, engineering biology, food-energy-water nexus, and next-generation electronic devices, circuits, and systems. Through support of small businesses and academic partnerships with industry, ENG will help launch exciting technological innovations and support the Nation's innovation ecosystem.

ENG will strive to prepare the future engineering workforce through leadership in engineering education research and through providing hands-on research opportunities to both undergraduate and graduate students. Engineering education is undergoing major changes with significant increases in student enrollments across the Nation. At the same time, the engineering education ecosystem continues to face major challenges in attracting women and underrepresented minorities. ENG will continue to focus its investments to identify and support systemic innovations to meet these critical and compelling challenges.

ENG investments will support major Administration priorities and investments, such as the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, the Advanced Manufacturing Partnership (AMP), clean energy, the National Robotics Initiative (NRI), the National Strategic Computing Initiative (NSCI), and the Strategy for American Innovation. Targeted ENG investments will make unique and essential contributions to these far-reaching national challenges.

ENG also will lead or contribute directly in NSF-wide strategic investments in programs such as Risk and Resilience, Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS), Understanding the Brain (UtB), NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science), Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS), and the NSF Innovation Corps (I-Corps™).

ENG provides about 40 percent of federal funding for basic research at academic institutions in the engineering sciences.



FY 2009 reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- CBET's FY 2017 Request will support research and education in areas of the food, energy, and water nexus by contributing to the NSF-wide INFEWS investment, and will continue to support transformative work in neurotechnology through the UtB initiative. CBET will bolster CEMMSS support through investments in advanced biomanufacturing that focus on studying theories and technologies of design, engineering, and manufacturing bio-related (natural or synthetic) products; and robotics research to assist those with physical disabilities or cognitive impairments. CBET will enhance support of research in Engineering Biology to improve the ability to engineer biological systems that could help address major economic and societal challenges in energy, the environment, sustainable manufacturing, and healthcare. The division will increase investment in novel ideas for clean energy technologies, and will continue to support a Science and Technology Center (STC).

- CMMI's FY 2017 Request will enable contributions to the CEMMSS investment through research and education in advanced manufacturing; robotics; interdisciplinary research in advanced materials and manufacturing processes; scalable nanomanufacturing; cyber-manufacturing to enable research on the networked integration of manufacturing machines, equipment, and systems into an increasingly accessible manufacturing service infrastructure; and cyber-physical systems with a stronger emphasis on Smart and Connected Communities to enable innovative applications and services for more livable, workable, and sustainable communities. CMMI will contribute to the NSF-wide Risk and Resilience priority through the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program to deepen fundamental knowledge and stimulate innovations to improve resilience, interoperations, performance, and readiness in interdependent critical infrastructure systems. Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) support will focus on research and education on computational-based approaches for engineering design, analysis, and predictive modeling, particularly under high degrees of uncertainty.

- ECCS's FY 2017 Request will enable its support to critical areas of national importance such as UtB and clean energy technology. The division will contribute to CEMMSS through supporting research in robotics, smart health research, and cyber-physical systems in the area of integration of intelligent decision-making algorithms and hardware into physical systems. ECCS will continue to support fundamental research in cyber-physical systems with an emphasis on Smart and Connected Communities applications. The goal is to advance the effective integration of networked computing systems, physical devices, data sources, and infrastructure to transform society, allow cities, communities, and regions to surmount deeply interlocking physical, social, economic, and infrastructural challenges. In FY 2017, ECCS will continue the phase-down of formal CIF21 research activities and plans to shift the investment to the NSCI through supporting research to enable low-power computing and future high-performance computing (HPC) systems in the post-Moore's Law device and hardware systems era. Leveraging NSF's CIF21 investments, ECCS will continue to support data-intensive science and research activities building on ECCS-led Dynamic Data Systems in partnership with the Air Force Office of Scientific Research. FY 2016 is the final year of formal investment in the Enhancing Access to the Radio Spectrum (EARS) program. Building on the EARS investment and through its core and crosscutting programs, ECCS will continue to support research on more efficient radio spectrum use and greatly improved low-power energy-conserving device technologies, and emphasize research in the millimeter-wave and terahertz bands. ECCS will also continue to support an STC.

- EEC's FY 2017 Request will provide funding for a combination of Engineering Research Centers (ERCs) and Nanosystems Engineering Research Centers (NERCs), including planned growth supplements for the three centers awarded in the ERC Class of 2015. In FY 2017, EEC will continue support of Improving Undergraduate STEM Education (IUSE)/Professional Formation of Engineers: REvolutionizing engineering and computer science Departments (IUSE/PFE:RED), which enables engineering departments to achieve significant sustainable changes necessary to overcome long-standing issues in their undergraduate programs and educate inclusive communities of engineering students prepared to solve 21st century challenges. PFE:RED is under the framework of the NSF-wide IUSE initiative, which integrates the agency's investments in undergraduate education. EEC will continue to support research and innovations leading to and propagating interventions that improve both the quality and quantity of STEM graduates. (For more information regarding IUSE and NSF's undergraduate framework, see the IUSE narrative in the NSF-Wide Investments chapter.) Support for the Research Experiences for Undergraduates (REU) program will be maintained, with a particular focus on providing early opportunities to conduct research.

- IIP's FY 2017 Request reflects its commitment to enhancing the Nation's innovation ecosystem. Through programs for Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), IIP will continue to support technological breakthroughs that benefit society. Through the I-Corps™, Partnerships for Innovation (PFI), and Industry/University Cooperative Research Centers (I/UCRC) programs, as well as other activities, the division will enable academic researchers to translate fundamental research discoveries into market realities, and encourage academia and industry to collaborate and prepare students to be innovators and entrepreneurs.

- EFMA's FY 2017 Request will provide support for 16 Emerging Frontiers in Research and Innovation (EFRI) interdisciplinary teams to pursue cutting-edge research with the potential for transformative impacts on national needs and grand challenges. In FY 2016, ENG announced a Dear Colleague Letter (DCL) through EFMA for Germination of Research Ideas for Large Opportunities and Critical Societal Needs (GERMINATION). The DCL seeks EAGER (EArly-concept Grants for Exploratory Research) proposals with exploratory ideas to design learning frameworks, platforms and/or environments to enable early- and mid-career faculty, as well as graduate students and post-doctoral fellows to conceive research ideas and questions with potentially transformative outcomes. In FY 2017, ENG will continue to enable researchers to expand the long-term impacts of ENG's basic research investment.

Major Investments

ENG Major Investments

(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
ADVANCE	$3.26	$3.26	$3.26	-	-
BioMaPS	3.00	1.50	-	-1.50	-100.0%
CAREER	74.23	63.38	64.23	0.85	1.3%
CEMMSS	110.77	110.00	112.00	2.00	1.8%
Advanced Manufacturing	*95.77*	*82.00*	*84.00*	*2.00*	*2.4%*
Clean Energy Technology	138.00	140.87	177.38	36.51	25.9%
CIF21	10.00	8.00	4.00	-4.00	-50.0%
NSF I-Corps™	11.05	13.00	13.00	-	-
NSF INCLUDES	-	1.47	1.40	-0.07	-4.8%
INFEWS	-	10.00	13.00	3.00	30.0%
IUSE	4.94	6.00	6.00	-	-
NRT[1]	2.85	2.59	2.50	-0.09	-3.5%
NSCI	-	-	10.00	10.00	N/A
Risk and Resilience	12.00	12.00	14.00	2.00	16.7%
SaTC	3.25	3.25	3.25	-	-
SEES	19.39	3.00	3.00	-	-
Understanding the Brain	11.00	16.75	16.75	-	-
BRAIN Initiative	*11.00*	*16.75*	*16.75*	-	-

Major investments may have funding overlap and thus should not be summed.

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $1.13 million in FY 2015, $1.81 million in FY 2016, and zero funding in FY 2017.

- ADVANCE ($3.26 million): ENG will continue to participate in the NSF-wide program ADVANCE as part of its ongoing commitment to build strategies and models to increase the participation, retention, and advancement of women in all STEM academic careers.

- BioMaPS (-$1.50 million, to a total of zero): ENG formal support ends as funds transition to core programs to support engineering biology.

- Faculty Early Career Development (CAREER) (+$850,000, to a total of $64.23 million): Supports young investigators who exemplify the role of teacher–scholar through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations.

- CEMMSS (+$2.0 million, to a total of $112.0 million): Support will build upon existing frontier engineering research and advance connections among breakthrough materials, advanced manufacturing, robotics, and cyber-physical systems leading to transformative research.

- Advanced Manufacturing (+$2.0 million, to a total of $84.0 million): Provides support for research in nanosystems design and scalable nanomanufacturing; additional emphasis on the "Factory of the Future": Cyber-enabled, adaptive, agile, distributed, and secure manufacturing; and increased focus on advanced biomanufacturing. ENG will maintain close connections with efforts by other agencies to raise U.S. manufacturing capacity by ensuring appropriate links with the NSF investments in fundamental research and education in manufacturing.

- Clean Energy Technology (+$36.51 million, to a total of $177.38 million): ENG support of clean energy technology-related activities will enhance the fundamental scientific and engineering knowledge base to enable future clean energy technologies. Examples include research on theory and analytical tools for power networks with high levels of renewable energy generation; innovative processes for the sustainable production of electricity through renewable resources such as solar and wind energy; novel approaches to process intensification for biofuel and bioenergy; novel approaches to energy efficiency; and high-energy density and high-power density batteries suitable for transportation, and renewable energy storage applications. The ENG clean energy technology investment will be strategically coordinated across all divisions.

- CIF21 (-$4.0 million, to a total of $4.0 million): ENG support will focus on computational and data-enabled science and engineering research, infrastructure, and community-building, and access and connections to cyberinfrastructure facilities. Funding is in CBET, CMMI, and ECCS. In FY 2017, ENG will continue the phase-down of formal CIF21 research activities and plans to shift the investment to the NSCI through supporting research to enable low-power computing and future high-performance computing (HPC) systems in the post-Moore's Law device and hardware systems era.

- I-Corps™ ($13.0 million, equal to the FY 2016 Estimate): ENG will continue to lead the NSF-wide I-Corps™ program. In FY 2017, ENG will support I-Corps™ Teams, Sites, and Nodes to further build, utilize, and sustain a national innovation ecosystem that continues to augment the development of technologies, products, and processes that benefit the Nation. Funding is through IIP.

- NSF INCLUDES (-$70,000, to a total of $1.40 million): ENG investments are aligned with Foundation goals in this NSF-wide effort to increase participation of underrepresented groups in science, technology, engineering, and mathematics (STEM) fields.

- INFEWS (+$3.0 million, to a total of $13.0 million): ENG will continue to co-lead this NSF-wide initiative with the Directorate for Geosciences (GEO) in FY 2017. The goal is to catalyze the well-integrated interdisciplinary research efforts to transform understanding of the food-energy-water nexus to improve system function and management, address system stress, increase resilience, and ensure sustainability. ENG will focus on supporting fundamental engineering research to enable innovative system and technological solutions that address critical challenges in the food-energy-water nexus. INFEWS will leverage existing ENG programs in energy, water, and environmental technologies that support projects, for example, to reduce water consumption in power plants.

- IUSE ($6.0 million, equal to the FY 2016 Estimate): ENG will participate in the NSF-wide IUSE initiative, which integrates the agency's investments in undergraduate education. In FY 2017, ENG will continue to support IUSE/PFE:RED to enable research and innovations leading to and propagating interventions that improve both the quality and quantity of engineering graduates.

- NSF Research Traineeship (NRT) (-$90,000, to a total of $2.50 million): ENG will continue to participate in the NRT program, which is the successor to the Integrative Graduate Education and

Research Traineeship (IGERT) program. The FY 2017 amount reflects funding only for NRT awards, as all remaining commitments to the IGERT program were completed in FY 2016.

- National Strategic Computing Initiative (NSCI) ($10.0 million): ENG will support research to enable low-power computing and future high-performance computing (HPC) systems in the post-Moore's Law device and hardware systems era, partially supported by funds redirected from CIF21.

- Risk and Resilience (+$2.0 million, to a total of $14.0 million): ENG co-leads this priority area with GEO to advance knowledge of risk assessment and predictability, and to support the creation of tools and technologies for increased resilience. In FY 2017, ENG will continue to support the CRISP program by catalyzing collaborations among researchers across the domains of engineering, computer and computational science, and social, behavioral, and economic sciences to deepen fundamental knowledge and stimulate innovations to improve resilience, interoperations, performance, and readiness of our critical infrastructure.

- Secure and Trustworthy Cyberspace (SaTC) ($3.25 million, equal to the FY 2016 Estimate): ENG support for SaTC will focus on the engineering aspects of the Networking and Information Technology Research and Development (NITRD) Strategic Plan for the Federal Cybersecurity Research and Development Program. NITRD's research thrusts cover a set of interrelated priorities for U.S. government agencies that conduct or sponsor research and development in cybersecurity.

- SEES ($3.0 million, equal to the FY 2016 Estimate): ENG will continue to support Sustainable Chemistry research. FY 2017 represents the final year of investment as program activities sunset. Funds will be re-invested in INFEWS, Risk and Resilience, and other priorities within the ENG portfolio.

- UtB ($16.75 million, equal to the FY 2016 Estimate): ENG will invest in UtB, neuroscience and neurotechnology research critical to success of the BRAIN Initiative. Research will drive integration across scales and across disciplines, accelerate the development of novel experimental and analytical approaches, including computational and data-enabled modeling, and enable new neural engineering and technology research and innovation.

ENG Funding for Centers Programs and Facilities

ENG Funding for Centers Programs
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Centers Programs	**$74.54**	**$67.25**	**$71.75**	**$4.50**	**6.7%**
Engineering Research Centers (EEC)	59.69	56.50	61.00	4.50	8.0%
Nanoscale Science & Engineering Centers (Multiple)	4.00	0.75	0.75	-	-
Science of Learning Centers (EEC)	0.85	-	-	-	N/A
Science & Technology Centers (Multiple)	10.00	10.00	10.00	-	-

Totals may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- Engineering Research Centers (ERC): Support for the ERC program will increase (+$4.50 million, to a total of $61.0 million). Building on the long-standing ERC program model, this funding level will provide support for 14 existing centers and the addition of four new ones as part of the FY 2017 competition.

- Nanoscale Science and Engineering Centers (NSEC): Support remains at $750,000, equal to the FY 2016 Estimate, as the program continues to sunset as planned. It is anticipated core programs in ENG will increase support to nanoscale science and engineering, offsetting the reduction.

- Science of Learning Centers (SLC): Final funding commitments for SLCs ended in FY 2015.

- Science and Technology Centers (STC): ENG will continue to support two STCs in FY 2017. CBET will support the Center on Emergent Behaviors of Integrated Cellular Systems, and ECCS will support the Center for Energy Efficient Electronics Science.

ENG Funding for Facilities

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Facilities	**$33.53**	**$28.33**	**$28.33**	**-**	**-**
Cornell High Energy Synchrotron Source (CHESS)	5.00	5.00	5.00	-	-
National Nanotechnology Coordinated Infrastructure (NNCI)	10.29	10.83	10.83	-	-
Natural Hazards Earthquake Engineering Research Infrastructure (NHERI)	18.24	12.50	12.50	-	-

Totals may not add due to rounding.

For detailed information on individual facilities, please see the Facilities chapter.

- Support for CHESS operations and maintenance costs are maintained at $5.0 million, equal to the FY 2016 Estimate.

- ENG continues support for nanotechnology research infrastructure through investment in the National Nanotechnology Coordinated Infrastructure (NNCI) at $10.83 million, equal to the FY 2016 Estimate. This network of user facilities replaced the National Nanotechnology Infrastructure Network (NNIN) in FY 2015.

- Support for the Natural Hazards Engineering Research Infrastructure is $12.50 million, equal to the FY 2016 Estimate. Funding for this facility network is consistent with operations support for the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), which ended in FY 2015.

Summary and Funding Profile

ENG investment supports basic engineering research, engineering education, and innovation, as well as research infrastructure such as facilities.

In FY 2017, the number of research grant proposals to ENG is expected to be about 10,200. ENG expects to award approximately 2,000 research grants in FY 2017. Average annualized award size and duration are estimated to be $123,000 and three years, respectively, in FY 2017.

In FY 2017, funding for centers accounts for nine percent of ENG's non-SBIR/STTR Request.

In FY 2017, funding for facilities is just over three and one-half percent of ENG's non-SBIR/STTR Request.

ENG Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	12,236	12,500	13,500
Number of New Awards	2,504	2,500	2,700
Funding Rate	20%	20%	20%
Statistics for Research Grants:			
Number of Research Grant Proposals	9,332	9,500	10,200
Number of Research Grants	1,851	1,850	2,000
Funding Rate	20%	19%	20%
Median Annualized Award Size	$103,355	$103,000	$104,000
Average Annualized Award Size	$122,201	$122,000	$123,000
Average Award Duration, in years	2.7	3.0	3.0

Program Monitoring and Evaluation

<u>External Program Evaluations and Studies</u>

- A study of the feasibility of performing rigorous impact evaluation of the NSF I-Corps™ Teams program was completed in FY 2014. Based on the feasibility study, NSF initiated a request for proposals to identify a contractor to perform a rigorous evaluation of the I-Corps™ Teams. A contractor was selected and engaged in FY 2015. The study will be initiated in FY 2016.
- During the first half of FY 2015, ENG completed a pilot test of the principal investigator (PI) survey questionnaire that evolved from the logic model developed for the Emerging Frontiers in Research and Innovation (EFRI) program. The study demonstrated that a longitudinal outcome data collection effort is fruitful and possible. The response rate from the PIs was over 75 percent. PIs reported an acceptable level of burden by this additional data collection, as well as being positive about the availability of data needed to respond. A permanent longitudinal outcome monitoring system for the EFRI program will be developed and a contract issued in the second quarter of FY 2016.
- In the first quarter of FY 2015, IIP completed the development of theories of action for all its programs. ENG initiated a data collection effort for all IIP programs.
- In FY 2017, ENG will utilize the developing business intelligence platform and the output data available from the Research Performance Progress Report (RPPR) and public access to create dashboards and automated reports aimed at visualizing the output of programs, clusters, divisions, and the directorate, and their relationships with other factors and variables.

Workshops and Reports

- With support from CMMI, a two-day workshop[1] was held at the University of Florida from October 14 – 15, 2014, to explore the environmental and human health implications of the emerging field of additive manufacturing. This workshop was designed to build on a previous NSF-funded workshop held in July 2013, Frontiers of Additive Manufacturing Research and Education. The October 2014 workshop explored five areas of additive manufacturing, including lifecycle impacts (supply chain footprint from material extraction to finished product); energy use (quantification of energy use of additive vs conventional manufacturing); waste (minimizing end-of-life impacts); occupational health impacts (design to minimize emissions and exposure control); and cross-cutting/policy issues (associated environmental and occupational health issues to communicate to agencies such as the National Institute for Occupational Safety & Health, the Environmental Protection Agency, or the National Institutes of Health. The workshop informed the NSF program directors and the research community of emerging needs and opportunities in associated research.

- With support from CMMI, a three-day workshop on Advanced Manufacturing for the Oil and Gas Energy Industry[2] was held in Houston, Texas, from November 2 – 4, 2014. Attendees included representatives of industry; researchers, educators; and administrators and decision-makers who support and facilitate research, education, and technology transfer. Workshop attendees identified research needs to advance drilling processes; development of advanced material processing technologies such as nano-structured coatings that are resistant to fatigue, corrosion damage, extreme temperature and pressures; development of decision tools to relate various system design parameters to performance metrics; development and deployment of sensors, high temperature electronics and telemetrics to collect data; and advances in data analytics to bridge information gaps to improve performance control. The role of public–private partnership was stressed, as was the continuing challenge of workforce development.

- CBET sponsored a study by the National Academies on Industrialization of Biology. The National Academies Press published a report in 2015, titled "The Industrialization of Biology: A Roadmap to Accelerate the Advanced Manufacturing of Chemicals."[3] Major biotechnology advances have been made in the past decade, such as rapid, low-cost DNA sequencing, metabolic engineering, and high-throughput screening. The report puts forth a proactive strategy through the development of a technical roadmap to help realize the widespread benefits of accelerating the industrialization of biology.

- ECCS supported a March 2015 workshop, Rebooting the IT Revolution: A Call to Action,[4] in collaboration with the Semiconductor Industry Association (SIA), Semiconductor Research Corporation (SRC), the National Institute of Standards and Technology (NIST) and the Defense Advanced Research Projects Agency (DARPA). The purpose of this two-day workshop involving leaders from the tech industry and academia was to define Grand Challenges that will identify long-term research priorities in support of the upcoming IT revolution. Increasing societal expectations to access information anywhere, anytime, and deepening infusion of information technology in the physical world demand the development of a robust information technology infrastructure that connects the physical and virtual worlds. To determine ways to meet this demand, to fully realize Internet of Things breakthroughs, and to sustain America's technology leadership, workshop participants discussed needs for fundamental research for energy-efficient sensing and computing, data storage, real-time communication ecosystem, multi-level and scalable security, a new fabrication paradigm and insight computing. Many of these areas align with federal research initiatives, including the NSCI, the BRAIN

[1] www.wilsoncenter.org/sites/default/files/nsf_am_env_final_red.pdf
[2] ise.tamu.edu/nsf2014/PDFs/NSF-OGWorkshop-Report_Feb_2015.pdf
[3] nap.edu/catalog/19001/industrialization-of-biology-a-roadmap-to-accelerate-the-advanced-manufacturing
[4] src.org/newsroom/rebooting-the-it-revolution.pdf

Initiative, and the National Nanotechnology Initiative Grand Challenges.

<u>Committees of Visitors (COV)</u>

- In 2015, COVs reviewed CBET and CMMI. The COVs presented their reports to the ENG Advisory Committee, which convened in April and October of 2015. Both COV reports were approved by the ENG Advisory Committee.
- In 2016, COVs will review EEC and IIP.
- In 2017, COVs will review ECCS and EFMA.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in ENG Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	9,220	9,300	10,000
Other Professionals	1,856	1,900	2,100
Postdoctoral Associates	539	550	600
Graduate Students	7,523	7,600	8,200
Undergraduate Students	3,968	4,000	4,200
Total Number of People	**23,106**	**23,350**	**25,100**

DIVISION OF CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, AND TRANSPORT SYSTEMS (CBET) $198,420,000 +$14,600,000 / 7.9%

CBET Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, CBET	**$180.40**	**$183.82**	**$198.42**	**$14.60**	**7.9%**
Research	**174.47**	**178.98**	**193.58**	**14.60**	**8.2%**
CAREER	33.26	27.19	27.56	0.37	1.4%
Centers Funding (total)	6.24	5.33	5.33	-	-
Nanoscale Science & Engineering Centers	1.24	0.33	0.33	-	-
STC: Center for Emergent Behavior of Integrated Cellular Systems	5.00	5.00	5.00	-	-
Education	**2.25**	**1.15**	**1.15**	**-**	**-**
Infrastructure	**3.68**	**3.69**	**3.69**	**-**	**-**
NNCI	3.68	3.69	3.69	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for CBET is $198.42 million, of which $187.18 million is discretionary funding and $11.24 million is new mandatory funding. The mandatory funding is within the research line in the above table.

CBET supports research to enhance and protect U.S. national health, energy, food, water, environment, process manufacturing, and security. Through CBET, the physical, chemical, life, and social sciences are integrated in engineering research and education, resulting in advances in the rapidly evolving fields of biotechnology, bioengineering, biomanufacturing, advanced materials, environmental engineering, and sustainable energy. CBET also invests in areas that involve the transformation and/or transport of matter and energy by chemical, thermal, or mechanical means. CBET investments contribute significantly to the knowledge base and to the workforce development of major U.S. economy components, including chemicals, pharmaceuticals, medical devices, specialty chemicals, and materials for advanced manufacturing, natural gas and petroleum production, food, textiles, utilities, and microelectronics.

CBET supports the chemical, environmental, biomedical, mechanical, civil, and aerospace engineering disciplines. To serve these communities and achieve its goals, CBET is organized into four thematic clusters: Chemical and Biochemical Systems; Bioengineering and Engineering Healthcare; Environmental Engineering and Sustainability; and Transport, Thermal, and Fluid Phenomena.

In general, 76 percent of the CBET portfolio is comprised of new research grants, and 24 percent supports continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>

- CAREER funding increases by $370,000, to a total of $27.56 million in FY 2017. This increase is consistent with CBET's emphasis on supporting early-career researchers.

- Support for NSF-wide INFEWS increases by $3.0 million, to a total of $8.0 million, focusing on fundamental engineering research to enable innovative system and technological solutions that address critical challenges in the food-energy-water nexus. CBET programs invest in fundamental engineering research in energy, water, and biotechnology, and in research projects focusing on sustainable water and energy use. Support will also be provided for projects to advance the understanding of the complex food-energy-water system and water-energy, food-energy, and food-water subsystems, as well as their interdependencies.
- Support for UtB research totals $7.0 million, equal to the FY 2016 Estimate. This activity holds promise for revealing fundamental principles underlying brain structure and function and for enhancing understanding of the brain through the development of new technologies and theories. Support will focus on proposals from interdisciplinary teams of researchers poised to promptly address targeted issues in frontier experimentation; neurotechnology innovation; modeling and simulation; and quantitative theory development. One major objective of these investments is to establish truly transdisciplinary team-based brain research that rises above the work of existing disciplines.
- CBET will enhance support of research in Engineering Biology to improve the ability to engineer biological systems that could help address major economic and societal challenges in energy, the environment, sustainable manufacturing, and healthcare. CBET support encompasses fundamental engineering research in synthetic biology, systems biology, metabolic engineering, and protein engineering and design, as well as the creation of new tools and technologies that have enormous potential to revolutionize biomanufacturing, to enable new materials, and to foster innovative solutions that will allow the unraveling of the mysteries of complex biological systems.
- CBET will continue to enhance support for research in advanced biomanufacturing that focuses on studying theories and technologies of design, engineering, and manufacturing bio-related (natural or synthetic) products, such as cells and cell-based therapeutic products (i.e., proteins, individualized tissues, and organoids), or devices with biomaterials and/or cells as components. This program will leverage the Biomedical Engineering and the Biotechnology and Biochemical Engineering programs in CBET.
- The division will provide $2.0 million in support of the national Materials Genome Initiative (MGI), through a collaborative effort with the Directorate for Mathematical and Physical Sciences (MPS) in Designing Materials to Revolutionize and Engineer our Future (DMREF) under the NSF-wide CEMMSS initiative.
- STC funding remains $5.0 million, equal to the FY 2016 Estimate, to continue support for the STC on Emergent Behaviors of Integrated Cellular Systems, led by the Massachusetts Institute of Technology.
- CBET support for the NSEC program totals $330,000, as the program continues to sunset as planned.

Education

- CBET contributes to a number of education and diversity activities, including REU and NSF's Career Life Balance (CLB) activities. Total CBET funding for these activities in the FY 2017 Request is $1.15 million.

Infrastructure

- CBET continues support for infrastructure in FY 2017 through investments in the NNCI at the FY 2016 Estimate level.

DIVISION OF CIVIL, MECHANICAL, AND MANUFACTURING INNOVATION (CMMI) $233,920,000 +$17,530,000 / 8.1%

CMMI Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, CMMI	**$225.55**	**$216.39**	**$233.92**	**$17.53**	**8.1%**
Research	**203.07**	**200.24**	**217.82**	**17.58**	**8.8%**
CAREER	24.20	21.12	21.40	0.28	1.3%
Centers Funding (total)	1.04	0.31	0.31	-	-
Nanoscale Science & Engineering Centers	1.04	0.31	0.31	-	-
Education	**2.35**	**1.75**	**1.70**	**-0.05**	**-2.9%**
Infrastructure	**20.14**	**14.40**	**14.40**	**-**	**-**
NHERI	18.24	12.50	12.50	-	-
NNCI	1.90	1.90	1.90	-	-

Totals may not add due to rounding. FY 2015 Actual includes $11.32 million in carryover from prior fiscal year.

The FY 2017 Budget Request for CMMI is $233.92 million, of which $220.67 million is discretionary funding and $13.25 million is new mandatory funding. The mandatory funding is within the research line in the above table.

CMMI funds fundamental research in support of the Foundation's strategic goals directed at advances in the disciplines of civil, mechanical, industrial, systems, manufacturing, and materials engineering. In addition, the division has a focus on the reduction of risks and damage resulting from earthquakes, wind, and other hazards. CMMI encourages discoveries enabled by the use of cross-cutting technologies such as adaptive systems, nanotechnology, and high-performance computational modeling and simulation. The division promotes cross-disciplinary research partnerships at the intersections of traditional research disciplines to achieve transformative research results that promote innovative manufacturing technology; enable the design and analysis of complex engineered systems; enhance the sustainability and resilience of U.S. infrastructure (for example, buildings, transportation, and communication networks); help protect the Nation from extreme natural and human-induced events; and apply engineering principles to improve the Nation's service and manufacturing enterprise systems, including healthcare.

In general, 82 percent of the CMMI portfolio is comprised of new research grants and 18 percent supports continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>

- CAREER funding increases by $280,000, to a total of $21.40 million, in FY 2017. This increase is consistent with CMMI's emphasis on supporting early-career researchers.
- Fundamental core research in support of advanced manufacturing will increase by $2.0 million, to a total of $52.90 million, as part of the NSF-wide CEMMSS activity. Areas of continued emphasis include nanomanufacturing, cybermanufacturing, materials engineering and processing, service and manufacturing enterprise systems and operations research, smart manufacturing, and design and manufacturing of complex engineered systems.

- Research to support NRI will be maintained at $5.0 million as part of the NSF-wide CEMMSS activity to help ensure continued U.S. leadership in the robotics field.
- The division will maintain funding of $7.0 million in support of the national MGI through the DMREF effort under the NSF-wide CEMMSS investment area.
- Support for the agency's Risk and Resilience focus through the CRISP program will increase $2.0 million, to a total of $10.0 million. The CRISP program will (1) foster an interdisciplinary research community of engineers, computer and computational scientists, and social and behavioral scientists that will create new approaches and engineering solutions for the design and operation of infrastructure processes and services; (2) enhance the understanding and design of Interdependent Critical Infrastructure (ICIs) systems and processes that provide essential goods and services despite disruptions and failures from any cause – natural, technological, or malicious; (3) create the knowledge for innovation in ICIs so that they safely, securely, and effectively expand the range of goods and services they enable; and (4) improve the effectiveness and efficiency with which ICIs deliver existing goods and services.
- Leveraging NSF's long-standing investment in Cyber–Physical Systems (CPS), CMMI will continue to support research in smart and connected communities to enable innovative applications and services for more livable, workable, and sustainable communities.
- Support for CIF21 is reduced by $1.00 million, to a total of $2.60 million, in FY 2017 as focus shifts to investments in NSCI. Within CIF21 and NSCI, CMMI will continue to support research on computationally-based approaches for engineering design, analysis, and predictive modeling, particularly under high degrees of uncertainty. Efforts will support research in the areas of data-enabled science and engineering, with emphasis on complex systems design and analysis, and methods to utilize disparate and distributed data sets for CMMI-relevant research. Linkages between CEMMSS-related research programs and elements of the CIF21 and NSCI activity will be strengthened, as researchers make greater use of modeling and simulation, and data-enabled capabilities made possible by CIF21 investments.
- CMMI support for the NSEC program totals $310,000, equal to the FY 2016 Estimate, as the program continues to sunset as planned.

Education

- CMMI contributes to a number of education and diversity activities, including REU and CLB. Total CMMI funding for these activities in the FY 2017 Request is $1.70 million.

Infrastructure

- Support for NHERI is maintained at $12.50 million. NHERI is the successor to NEES, which received final year funding of $18.14 million in FY 2014 and ceased operations in FY 2015. The reduction in overall operations costs from the previous facility follows recommendations from numerous studies that indicated a need for a leaner and more focused facilities program for earthquake engineering simulation. The reduction in facilities and operational costs enables additional investments to be made in research that addresses engineering strategies to design for and mitigate against multiple hazards including earthquakes, wind, storm surge, and combinations of these and other potential hazards.
- ENG continues support for infrastructure through investments in the NNCI at the FY 2016 Estimate level.

DIVISION OF ELECTRICAL, COMMUNICATIONS, AND CYBER SYSTEMS (ECCS) — $122,770,000 +$8,820,000 / 7.7%

ECCS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, ECCS	**$118.97**	**$113.95**	**$122.77**	**$8.82**	**7.7%**
Research	**112.70**	**107.71**	**116.58**	**8.87**	**8.2%**
CAREER	16.77	15.07	15.27	0.20	1.3%
Centers Funding (total)	5.68	5.11	5.11	-	-
Nanoscale Science & Engineering Centers	0.68	0.11	0.11	-	-
STC: Center for Energy Efficient Electronics	5.00	5.00	5.00	-	-
Education	**1.56**	**1.00**	**0.95**	**-0.05**	**-5.0%**
Infrastructure	**4.71**	**5.24**	**5.24**	**-**	**-**
NNCI	4.71	5.24	5.24	-	-

Totals may not add due to rounding. FY 2015 Actual includes $6.48 million in carryover from prior fiscal years.

The FY 2017 Budget Request for ECCS is $122.77 million, of which $115.80 million is discretionary funding and $6.97 million is new mandatory funding. The mandatory funding is within the research line in the above table.

ECCS addresses fundamental research issues underlying electronic and photonic devices and component technologies, radio frequency through terahertz circuit integration, nanoelectronics, bioelectronics, energy (including alternate energy sources), power, smart-grid, controls, computation, networking, communications, control, sensing, robotics, and cyber–physical technologies. The division supports fundamental research of novel electronic and photonic devices, the integration of these devices into circuit and system environments, and the networking of intelligent systems at multiple scales for applications in energy, healthcare, disaster mitigation, telecommunications, environment, manufacturing, and other systems-related areas. ECCS research and education investments emphasize interdisciplinary collaboration and the convergence of technologies to take on major technological challenges for the next generation of innovative devices and systems.

In general, 81 percent of the ECCS portfolio is comprised of new research grants and 19 percent supports continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER funding increases by $200,000, to a total of $15.27 million, in FY 2017. This increase is consistent with ECCS's emphasis on supporting early-career researchers.
- Support for CIF21 activities will decrease $400,000, to a total of $400,000 as funding transitions to the NSCI. Building on the CIF21 investment, ECCS plans to invest in NSCI through supporting research to enable future HPC systems in the post-Moore's Law device and hardware systems era.
- The division's investment in NRI ($2.50 million, unchanged from the FY 2016 Estimate) is part of the NSF-wide CEMMSS portfolio and will support the integration of electronic, mechanical, computing,

sensing devices and systems, controls, and intelligent systems that enable ubiquitous, advanced robotics to be realized.

- In an ongoing collaboration with the Directorate for Computer and Information Science and Engineering (CISE), the division will support research on CPS totaling $4.50 million, unchanged from the FY 2016 Estimate. The ECCS investment is part of the NSF-wide CEMMSS portfolio and will be directed towards the integration of intelligent decision-making algorithms and hardware into physical systems.
- Leveraging investment in CPS, ECCS will continue to support fundamental research to enable Smart and Connected Communities. ECCS will support activities focused on multidisciplinary research, enabling effective integration of networked computing systems, physical devices, data sources, and infrastructure to transform society, allow cities, communities, and regions to surmount deeply interlocking physical, social, economic, and infrastructural challenges.
- Support will continue for multidisciplinary research in the optics and photonics area, with emphasis on nanoscale devices and systems. Applications in high-speed optical communications and environmental and biomedical research will be encouraged.
- ECCS will maintain support at $2.50 million for UtB research that aims for the development of innovative technologies, tools and instrumentation, theory, and models that will accelerate the integration of knowledge across multiple experimental scales and across science, engineering, and computational disciplines. ECCS will focus on research in noninvasive and minimally invasive brain imaging by sensing electric and magnetic fields. Projects may include novel high-sensitivity sensors and sensing algorithms to enhance spatial and temporal resolutions.
- Formal support for EARS ends in FY 2016. Building on previous EARS investments through its core and crosscutting programs, ECCS will continue to support and emphasize research on more efficient radio spectrum use and greatly improved low-power energy-conserving device technologies, and emphasize research in the millimeter-wave and terahertz bands.
- ECCS funding of $5.0 million maintains support for the STC for Energy Efficient Electronics Science, led by the University of California at Berkeley and awarded in FY 2010.
- ECCS support for the NSEC program is maintained at the FY 2016 Estimate, as the program continues to sunset as planned.

Education

- ECCS contributes to a number of education and diversity activities, including REU and CLB. Total ECCS funding for these activities in the FY 2016 Request is $950,000, a reduction of $50,000 from the FY 2016 Estimate.

Infrastructure

- ENG maintains support for infrastructure through investments in the NNCI at the FY 2016 Estimate.

DIVISION OF ENGINEERING EDUCATION AND CENTERS (EEC) $120,320,000 +$12,710,000 / 11.8%

EEC Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, EEC	**$117.95**	**$107.61**	**$120.32**	**$12.71**	**11.8%**
Research	**91.59**	**82.87**	**95.39**	**12.52**	**15.1%**
Centers Funding (total)	61.57	56.50	61.00	4.50	8.0%
Engineering Research Centers	59.68	56.50	61.00	4.50	8.0%
Nanoscale Science & Engineering Centers	1.04	-	-	-	N/A
Science of Learning Centers	0.85	-	-	-	N/A
Education	**26.36**	**24.74**	**24.93**	**0.19**	**0.8%**

Totals may not add due to rounding. FY 2015 Actual includes $200,000 in carryover from prior fiscal year.

The FY 2017 Budget Request for EEC is $120.32 million, of which $113.50 million is discretionary funding and $6.82 million is new mandatory funding. The mandatory funding is within the research line in the above table.

EEC integrates disciplinary basic research and education conducted in other divisions of ENG and across NSF into strategic frameworks critical for addressing societal grand challenges and promoting innovation. Research included in the EEC portfolio spans both the physical and life sciences and engineering, from nanostructured materials to new device concepts, subsystems, and systems. Applications range across a wide spectrum, including energy, medicine, telecommunications, nanoelectronics, manufacturing, civil infrastructure, the environment, computer networks, cybersecurity, and others. Also included are formal scholarly studies in engineering education and on professional formation of engineers.

The complex, integrative role of EEC requires a comprehensive infrastructure of people, equipment, and centers. Fresh, creative approaches to developing the engineering workforce are vital, as a lack of properly prepared engineers is a critical barrier to a healthy U.S. economy. EEC invests in faculty, graduate and undergraduate students, post-doctoral scholars, and K–12 teachers. As nontraditional students – such as part-time, delayed enrollment, veteran, and others – comprise more than 70 percent of the general undergraduate population, EEC is defining unique alternative pathways for these students, especially veterans, to successfully earn degrees in engineering.

The programs in EEC are administratively managed within three categories: (1) Major Centers and Facilities; (2) Engineering Education Research; and (3) Engineering Career Development. The Major Centers and Facilities category is comprised of the signature ERC program and NSECs. They provide the framework for interdisciplinary research and education, development, and technology transfer in partnership with academia, industry, and government. The Engineering Education Research category advances new productive engineering pedagogy and learning strategies in traditional and non-traditional environments. This category also includes EEC's participation in the NSF-wide activity, IUSE, which integrates the agency's investments in undergraduate education. The Engineering Career Development category includes programs such as REU and Research Experiences for Teachers (RET).

In general, 28 percent of the EEC portfolio is comprised of new research grants. The remaining 72 percent funds continuing grants and cooperative agreements made in previous years. This high fraction of multi-year commitments is primarily a consequence of centers funding, which includes awards made as five-year cooperative agreements.

FY 2017 Summary
All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Support for the ERC program increases by $4.50 million, to a total of $61.0 million. This funding level provides support for 14 existing centers and the addition of four new ones through the FY 2017 competition. The ERC program supports basic and translational research of national priorities such as water, clean energy, advanced manufacturing, and critical civil infrastructure. The program will also invest in research related to NSCI to enable future HPC systems in the post-Moore's law device and hardware systems era. EEC's ERC portfolio includes four Nanosystems ERCs: three that were first supported in FY 2012 and one funded as part of the Class of FY 2015.

Education

- In FY 2014, NSF adopted a comprehensive agency-wide framework — IUSE — that consolidates NSF's investments in undergraduate education. While the majority of funding for IUSE is provided through the Directorate for Education and Human Resources (EHR), other NSF directorates contribute directly to this effort, ensuring an enduring connection to established discipline-based activities and expertise. In FY 2017, EEC will contribute $6.0 million towards IUSE-related activities, equal to the FY 2016 Estimate.
- In FY 2017, EEC will continue to support IUSE/Professional Formation of Engineers: REvolutionizing engineering and computer science Departments (IUSE/PFE:RED) to enable engineering departments to achieve significant sustainable changes necessary to overcome long-standing issues in their undergraduate programs and educate inclusive communities of engineering students prepared to solve 21st century challenges.
- Funding for the REU Sites program increases by $250,000, to a total of $10.75 million. REU projects involve students in meaningful ways in ongoing research programs or in research projects specifically designed for the REU program, who has been found to be one of the most effective avenues for attracting and retaining students in engineering and for preparing them for careers in this field. REU projects also offer an opportunity to tap the Nation's diverse student talent pool and broaden participation in science and engineering.
- Funding for RET increases by $100,000, to a total of $4.25 million. Over the past ten years, the RET in Engineering Sites program has provided K–12 teachers and community college faculty the opportunity to gain research experience in university laboratories. The professional development gained by the participants through this unique experience has enriched their performance in the classroom and their guidance of students toward engineering. The increase will support these participants in areas of national need such as sustainability, energy, manufacturing, robotics, and others.
- EEC will provide $1.40 million to support the agency's broadening participation program NSF INCLUDES.
- Support of NRT, a modernization of the IGERT program, decreases by $90,000, to a total of $2.50 million. The FY 2017 decrease reflects funding of the remaining commitments to IGERT awards.

DIVISION OF INDUSTRIAL INNOVATION AND PARTNERSHIPS (IIP) $268,900,000 +$28,970,000 / 12.1%

IIP Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, IIP	**$227.26**	**$239.93**	**$268.90**	**$28.97**	**12.1%**
Research	**226.66**	**239.78**	**268.75**	**28.97**	**12.1%**
SBIR/STTR	177.11	188.56	213.26	24.70	13.1%
Education	**0.60**	**0.15**	**0.15**	**-**	**-**

Totals may not add due to rounding.

The FY 2017 Budget Request for IIP is $268.90 million, of which $254.17 million is discretionary funding and $14.73 million is new mandatory funding. $3.14 million of the mandatory funding is within the research line in the above table. $11.59 million is provided for SBIR/STTR, consistent with the levels specified in the SBIR/STTR Reauthorization Act of 2011 (P.L 112-81), which stipulates 3.0 percent and 0.45 percent of NSF's FY 2017 extramural research funding be allocated to the SBIR and STTR programs, respectively.

IIP contributes to the NSF innovation ecosystem by: (1) supporting innovation research that builds on fundamental research discoveries that exhibit potential for societal and economic impact; (2) encouraging research partnerships between academia and industry; and (3) offering hands-on experience in the innovation process to current and future entrepreneurs and innovators.

IIP is home to two Federal small business research programs, the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program. These innovation research programs leverage academic research findings and build partnerships among small businesses, academia, large companies, and/or other stakeholders with the goal of achieving technology commercialization and enabling new products, processes, or services. SBIR and STTR technology topics draw upon the breadth of NSF scientific and engineering research disciplines and are aligned with national and societal priorities.

IIP supports academic research through three research programs: the Industry/University Cooperative Research Center (I/UCRC) program, the Partnerships for Innovation (PFI) program, and the Grant Opportunities for Academic Liaison with Industry (GOALI) program. These programs aim to stimulate academia–industry partnerships, leverage industrial support, accelerate technology commercialization, and empower future generations in science and engineering. University grantees in these programs collaborate with industry to create enabling technologies that meet national needs, such as managing the electrical power system, improving manufacturing and biological processing, and supporting new information and communications technologies.

The division also administers, and is a strong intellectual contributor to, the I-Corps™ program. The NSF I-Corps™ program connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, and fosters a national innovation ecosystem that links scientific discovery with technology development, societal needs, and economic opportunities.

In general, 93 percent of the IIP portfolio is comprised of new research grants and 7 percent supports continuing grants.

FY 2017 Summary
All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Funding for SBIR/STTR increases by $24.70 million, to a total of $213.26 million, consistent with the levels specified in the SBIR/STTR Reauthorization Act of 2011 (P.L 112-81), which stipulates 3.0 percent and 0.45 percent of NSF's FY 2017 extramural research funding be allocated to the SBIR and STTR programs, respectively. Increased support for SBIR/STTR will (1) provide more resources to the small business community to embark on cutting-edge, high-risk, and high-impact research projects; and (2) provide an opportunity for greater collaboration with the disciplinary divisions across NSF in the spirit of catalyzing technology commercialization of discovery research.
- Funding for the PFI program increases by $500,000, to a total of $22.0 million. The PFI program is an umbrella for two complementary components. The Building Innovation Capacity (BIC) component supports academic–industry partnerships that are led by an interdisciplinary academic research team with at least one industry partner. Through partnerships, BIC partners collaborate in the integration of technologies inspired by breakthrough discoveries into a specified human-centered smart service system with the potential to achieve transformational change in an existing service system or to spur an entirely new service system. The Accelerating Innovation Research (AIR) component is designed to enable research discoveries to be translated along a path toward commercial reality while engaging faculty and students in entrepreneurial and market-oriented thinking, leveraging prior NSF investments, and providing NSF-funded research alliances the opportunity to develop academic-based innovation ecosystems.
- Funding for the I-Corps™ program is maintained at $13.0 million. The I-Corps™ program provides entrepreneurial education for federally-funded scientists and engineers, pairing them with business mentors for an intensive curriculum focused on discovering a demand-driven path from their lab work to a marketable product. Since NSF launched the I-Corps™ program in 2011, 534 Teams have completed this experiential education, and approximately 45 percent of these Teams have started their own companies, and two of these companies have been acquired.
- Funding for I/UCRC increases by $500,000, to a total of $12.50 million. Support will emphasize topics related to advanced manufacturing, clean energy, and cyberinfrastructure, in line with NSF investments in CEMMSS, clean energy technology, and CIF21. Funding will also support REU, which will further enhance the educational impact of I/UCRCs by preparing students for innovation leadership in a globally competitive marketplace through opportunities to work closely with industry.
- IIP's support for GOALI increases by $130,000, to a total of $5.0 million. The program promotes university–industry partnerships by making project funds or fellowships/traineeships available to support an eclectic mix of industry–university linkages across the Foundation.

Education

- Support for the REU program, at $150,000, remains the same as the FY 2016 Estimate.

OFFICE OF EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES (EFMA) $58,400,000 +$3,910,000 / 7.2%

EFMA Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, EFMA	**$53.41**	**$54.49**	**$58.40**	**$3.91**	**7.2%**
Research	**45.09**	**46.13**	**50.04**	**3.91**	**8.5%**
Centers Funding (total)	0.02	-	-	-	N/A
Engineering Research Centers	0.02	-	-	-	N/A
Education	**3.32**	**3.36**	**3.36**	**-**	**-**
Infrastructure	**5.00**	**5.00**	**5.00**	**-**	**-**
CHESS	5.00	5.00	5.00	-	-

Totals may not add due to rounding. FY 2015 Actual includes $3.19 million in carryover from prior fiscal year.

The FY 2017 Budget Request for EFMA is $58.40 million, of which $55.09 million is discretionary funding and $3.31 million is new mandatory funding. The mandatory funding is within the research line in the above table.

EFMA strategically pursues and funds projects in important emerging areas in a timely manner. The office also provides support to multidisciplinary education programs such as Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE) and REU. Additionally, EFMA is the home to ENG’s annual operations support of the Cornell High Energy Synchrotron Source (CHESS) facility. The largest activity in EFMA is the Emerging Frontiers in Research and Innovation (EFRI) program.

Each year EFRI recommends, prioritizes, and funds interdisciplinary topics at the frontiers of engineering research and education that have the potential for transformative impacts on national needs and/or grand challenges. Technological innovations have given rise to new industries, expanded access to quality healthcare, and fueled prosperity even as global competition has grown. To help ensure the nation’s continued success, EFRI provides critical, strategic support of fundamental discovery, particularly in areas that may lead to breakthrough technologies and strengthen the economy’s technical underpinnings. EFRI will have the necessary flexibility to target long-term challenges, while retaining the ability and agility to adapt as new challenges demand.

EFRI encourages the engineering community to submit new and paradigm-shifting proposals at the interface of disciplines and fields in important emerging areas. Their ideas and discoveries may potentially lead to new research areas for NSF and other agencies, new industries or capabilities that result in a leadership position for the country, and/or significant progress on a recognized national need or grand challenge. Recent EFRI topics included areas such as: integrated processes and systems designed to make U.S. infrastructures more resilient; sustainable energy sources; advances in robotics; and flexible technologies and regenerative engineering for healthcare.

In FY 2014 – FY 2015, EFRI invested in 2-Dimensional Atomic Layer Research and Engineering (2-DARE), a topic managed jointly by ENG and MPS. The EFRI 2-DARE topic promotes the exploration of the exciting prospects of two-dimensional (2D) atomic layers and devices in the wide range of compositions beyond graphene that can stimulate technologically significant applications in the coming years.

In FY 2016, EFRI is investing in two new topic areas. The first topic, Advancing Communication Quantum Information Research in Engineering (ACQUIRE), aims to enhance secure, scalable, and efficient data communication. ACQUIRE researchers will investigate fundamental engineering challenges in quantum communication systems to enable lossless, room temperature, point-to-point links combining components, repeaters, networks, and architectures. The second topic, New Light and Acoustic Wave Propagation: Breaking Reciprocity and Time-Reversal Symmetry (NewLAW), may disrupt how electronic, photonic, and acoustic devices are designed and employed, and enable breakthroughs in secure communication, impact and blast protection, and smart infrastructure. EFRI is collaborating with MPS and CISE on these topics.

EFMA launched a consortium in FY 2015 to identify emerging areas of advanced manufacturing that would benefit from shared public–private investment in research and development, education, and training: the Alliance for Manufacturing Foresight. As recommended by the President's Council of Advisors on Science and Technology in its 2014 report, *Accelerating U.S. Advanced Manufacturing,*[5] the consortium will provide a channel for rapid input from industrial, academic and other private sectors on future manufacturing technologies. It will help align advanced manufacturing research with national priorities and challenges to ensure efficient use of federal and private funding for the greatest possible return on investment.

In FY 2015, EFMA also awarded a two-year grant to the National Academies of Science to study what future models for center-based, multidisciplinary engineering research, education and innovation could be most effective in a shifting global landscape. The study will encompass potential future opportunities, missions, measures and models for engineering research centers, and will evaluate center designs and features, such as partnerships, for their ability to achieve breakthrough discoveries and innovations and to prepare an inclusive, innovative engineering workforce.

In FY 2015, EFMA funded the Exploring Innovation Frontiers Initiative (EIFI), a two-year study to identify the emerging models of technological innovation that will propel U.S. competitiveness through rapid change in the coming decades. EIFI will also explore methods for tapping into the Nation’s innovation capacity, nurturing new talent and ideas, translating innovation into widespread prosperity, and growing national and regional economies.

In general, 73 percent of the EFMA portfolio is comprised of new research grants, and 27 percent supports continuing increments for grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- FY 2017 EFRI support increases by $500,000, to a total of $31.75 million, and will provide support for up to 16 interdisciplinary team projects aimed at addressing national challenges such as renewable energy, advanced manufacturing, and secure communication systems.
- An increase of $3.41 million, to a total of $15.63 million, is provided to support new and ongoing NSF-wide multidisciplinary investments and other important national priorities. This amount includes $2.50 million to enable researchers to formulate high-impact research ideas with the potential for transformative impacts on national needs and grand challenges. In FY 2016, ENG announced a Dear

[5] www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/amp20_report_final.pdf

Colleague Letter through EFMA for Germination of Research Ideas for Large Opportunities and Critical Societal Needs (GERMINATION). The DCL seeks EAGER (EArly-concept Grants for Exploratory Research) proposals with exploratory ideas to design learning frameworks, platforms and/or environments to enable early- and mid-career faculty, as well as graduate students and post-doctoral fellows to conceive research ideas and questions with potentially transformative outcomes. In FY 2017, ENG will continue to enable researchers to expand the long-term impacts of ENG's basic research investment.

Education

- EFMA support for the ADVANCE and REU programs are maintained at the FY 2016 Estimate of $3.26 million and $10,000, respectively.

Infrastructure

- EFMA maintains support for infrastructure through investment in CHESS.

DIRECTORATE FOR GEOSCIENCES (GEO) $1,393,830,000
+$80,300,000 / 6.1%

GEO Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Atmospheric and Geospace Sciences (AGS)	$252.18	$253.67	$267.92	$14.25	5.6%
Earth Sciences (EAR)	178.31	179.39	191.68	12.29	6.9%
Integrative and Collaborative Education and Research (ICER)	84.22	83.74	94.95	11.22	13.4%
Ocean Sciences (OCE)	361.31	359.89	379.42	19.53	5.4%
Polar Programs (PLR)	443.02	441.85	464.86	23.01	5.2%
U.S. Antarctic Logistical Support (USALS)	*[67.52]*	*[67.52]*	*[67.52]*	-	-
Total, GEO	**$1,319.04**	**$1,318.54**	**$1,398.83**	**$80.30**	**6.1%**

Totals may not add due to rounding.

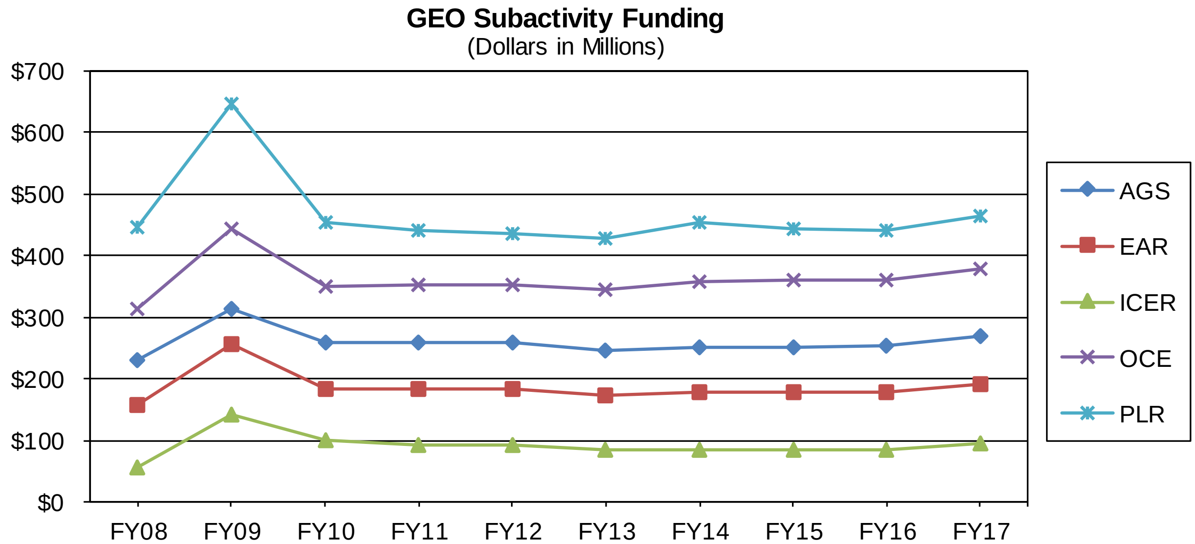
The FY 2017 Budget Request for GEO is $1,398.83 million, of which $1,319.56 million is discretionary funding and $79.27 million is new mandatory funding. The major focus of the mandatory funding is support for disciplinary and interdisciplinary research activities, principally through the support of early career investigators. Across the geosciences, special attention will be paid to new or early-career researchers. Most early-career researchers supported by GEO are funded through standing programs and increases to these activities should enable support of additional early-career researchers. Mandatory funding will also support one-time investments to enhance infrastructure at a number of key geoscience facilities. Increases include: NCAR ($1.03 million), GAGE ($1.50 million), SAGE ($2.60 million), Antarctic infrastructure ($8.0 million), and Arctic logistics ($3.0 million).

About GEO

GEO supports basic research that advances the frontiers of knowledge and drives technological innovation while improving our understanding of the many processes that affect the global environment. These processes include the planetary water cycle, geologic interactions that cross the land-ocean interface, and the behavior of ice sheets. Lives are saved and property is preserved through better prediction and understanding of natural environmental hazards such as earthquakes, tornados, hurricanes, tsunamis, drought, and solar storms. Basic research supported by GEO enables preparation for and subsequent mitigation of, or adaptation to, the effects of these and other disruptive natural events. Support is provided for interdisciplinary studies that contribute directly to national research priorities such as: mitigating the impacts of hazardous events; developing and deploying integrated ocean observing capabilities to support ecosystem-based management; and understanding future availability and distribution of fresh water. Another focus is understanding the Earth's polar regions – research that spans not only atmospheric, earth, and ocean processes, but other NSF-supported disciplines.

As the primary U.S. supporter of fundamental research in the polar regions, NSF, through GEO, provides interagency leadership for U.S. polar activities. In the Arctic, NSF helps coordinate research planning as directed by the Arctic Research Policy Act of 1984. The NSF Director chairs the Interagency Arctic Research Policy Committee created for this purpose, which is now a component of the President's National Science and Technology Council (NSTC). In the Antarctic, per Presidential Memorandum 6646, GEO manages all U.S. activities as a single, integrated program, making Antarctic research possible for scientists supported by NSF and by other U.S. federal agencies. The latter include the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), the Smithsonian Institution, and the Department of Energy (DOE). The U.S. Antarctic Program research activity funded by NSF also supports leadership by the U.S. Department of State in the governance of the continent and Southern Ocean under the aegis of the Antarctic Treaty.

GEO provides about 59 percent of the federal funding for basic research at academic institutions in the geosciences and polar regions.



FY 2009 reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- AGS's FY 2017 Request emphasizes support for two NSF-wide emphasis areas: 1) Risk and Resilience through PREEVENTS (Prediction of and Resilience against Extreme Events), and 2) the Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) investment. Support continues for the NSF-wide Science, Engineering, and Education for Sustainability (SEES) investment, which ends in FY 2017. AGS priorities include maintaining support for disciplinary and interdisciplinary research activities in atmospheric sciences, and in important geospace frontier areas, including understanding of space weather events, and the observational infrastructure required to conduct modern research, including overseeing operation of the National Center for Atmospheric Research (NCAR)-Wyoming Supercomputing Center.

- EAR's FY 2017 Request is focused on support for PREEVENTS and INFEWS. Supporting SEES, maintaining support for disciplinary and interdisciplinary research activities, and the observational infrastructure required to conduct modern research also remain priorities.

- ICER's FY 2017 Request includes support for PREEVENTS and INFEWS. Support will continue for priority areas such as Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) and SEES. GEO is initiating, through the ICER division, a new activity to support mid-scale research infrastructure, which will address those projects that are above the funding ceiling for the Major Research Infrastructure (MRI) program but below the threshold to be considered for

Major Research Equipment and Facilities Construction (MREFC) funding. ICER will also provide some support for the operations and maintenance of the Ocean Observatories Initiative (OOI), enabling OCE to maintain a strong research portfolio.

- OCE's FY 2017 Request includes support for basic ocean research, education, and infrastructure, as part of its internal programs as well as via the GEO initiatives PREEVENTS and INFEWS. OCE also supports SEES and partners with other NSF directorates in support of the Long-Term Ecological Research (LTER) program. OCE programs further support Executive Order 13547 establishing a National Ocean Policy (NOP).[1] OCE continues to invest in OOI and the International Ocean Discovery Program (IODP), and is continuing to develop potential new Regional Class Research Vessels (RCRV), construction funds for which are requested in the MREFC account.

- PLR's FY 2017 Request is focused on maintaining strong disciplinary programs; targeted basic research in cross-foundation and interagency priorities; and supporting and improving the efficiency of critical facilities that enable research in both polar regions, including planning to realize NSF's long-term vision for continued U.S. presence in Antarctica. Support is also provided for PREEVENTS and INFEWS.

Major Investments

GEO Major Investments
(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
ADVANCE	$4.11	$4.11	$4.11	-	-
CAREER	16.18	13.81	14.00	0.19	1.4%
CIF21	10.99	11.00	12.21	1.21	11.0%
NSCI	-	-	3.50	3.50	N/A
NSF I-Corps™	0.92	0.60	0.60	-	-
NSF INCLUDES	-	2.57	2.44	-0.13	-5.1%
INFEWS	-	5.00	10.00	5.00	100.0%
IUSE	10.90	6.50	6.00	-0.50	-7.7%
NRT[1]	6.63	4.43	3.32	-1.11	-25.1%
Risk and Resilience	-	17.75	17.75	-	-
SEES	59.00	34.00	18.50	-15.50	-45.6%

Major investments may have funding overlap and thus should not be summed.

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $2.04 million in FY 2015, $610,000 in FY 2016, and zero in FY 2017.

- ADVANCE: GEO will continue to participate in the NSF-wide program ADVANCE at a level of $4.11 million as part of its ongoing commitment to broaden participation to build strategies and models to increase the participation, retention, and advancement of women in all STEM academic careers.

- CAREER: GEO support for the CAREER program will increase $190,000, to a total of $14.0 million, reflecting GEO's continuing commitment to supporting the next generation of scientists.

[1] Executive Order 13547 – Stewardship of the Ocean, Our Coasts, and the Great Lakes. July 19, 2010. www.whitehouse.gov/the-press-office/executive-order-stewardship-ocean-our-coasts-and-great-lakes

- CIF21: GEO's investment will increase $1.21 million, to a total of $12.21 million in FY 2017. The increase is largely related to GEO's participation in the new Data Science Pilots activity.

- NSF Innovation Corps (I-Corps™): GEO support remains level at $600,000, reflecting continued support of I-Corps™ Nodes.

- National Strategic Computing Initiative (NSCI) ($3.50 million): As the role of large-scale computation in the geosciences expands, GEO will emphasize, through NSCI, activities to analyze the large complex data sets generated through modeling and simulations, and to assimilate real-time data into models and forecasts.

- NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science): In FY 2017, NSF continues to emphasize NSF INCLUDES, which started in FY 2016 and aims to promote broader participation in the sciences. GEO support decreases by $310,000, to a total of $2.44 million.

- INFEWS: In FY 2017, NSF is continuing to build an interdisciplinary investment to study the food-energy-water nexus through INFEWS. Support for this activity in FY 2017 totals $10.0 million, double the FY 2016 estimate.

- Improving Undergraduate STEM Education (IUSE): Support for the NSF-wide IUSE activity decreases by $500,000 to a total of $6.0 million.

- NSF Research Traineeship (NRT): GEO will continue to fund STEM graduate students in areas of national priority and support the development of transformative and scalable models for STEM graduate education. Support for NRT decreases to $3.32 million in FY 2017, reflecting the completion of funding commitments for the prior program IGERT.

- Risk and Resilience: In FY 2017, NSF is continuing a new activity to enhance national risk and resilience to hazardous events initiated in FY 2016. GEO plays a key role in advancing understanding of natural hazards such as tornados, hurricanes, earthquakes, and disruptive space weather events, and is maintaining its investment of $17.75 million in PREEVENTS.

- SEES: SEES programs began a planned ramp-down in FY 2015, and in FY 2017, this phase-out will continue. GEO support for SEES decreases $5.50 million, to $18.50 million.

GEO Funding for Centers Programs and Facilities

GEO Funding for Centers Programs

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Centers Programs	**$10.32**	**$5.00**	**$5.00**	-	-
Center for Multiscale Atmospheric Processes (AGS)	2.66	-	-	-	-
Center for Coastal Margin Observation and Prediction (OCE)	2.66	-	-	-	-
Center for Dark Energy Biosphere Investigations (OCE)	5.00	5.00	5.00	-	-

Totals may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- FY 2016 marks the planned retirement of two Science and Technology Centers (STC): the Center for Multiscale Atmospheric Processes in AGS and the Center for Coastal Margin Observation and Prediction in OCE. In FY 2017, OCE support continues for the Center for Dark Energy Biosphere Investigations at a level of $5.0 million.

GEO Funding for Facilities
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Facilities	**$645.61**	**$634.35**	**$643.80**	**$9.45**	**1.5%**
Academic Research Fleet (OCE)	82.00	86.80	84.80	-2.00	-2.3%
Arctic Research Support and Logistics (PLR)	56.78	39.41	42.41	3.00	7.6%
Arecibo Observatory (AGS)	4.00	4.10	4.10	-	-
Geodesy Advancing Geosciences and EarthScope (EAR)	11.58	11.58	13.08	1.50	13.0%
IceCube Neutrino Observatory (PLR)	3.45	3.45	3.50	0.05	1.4%
International Ocean Discovery Program (OCE)	48.00	48.00	48.00	-	-
National Center for Atmospheric Research (AGS)	98.70	99.70	101.00	1.30	1.3%
National Nanotechnology Coordinated Infrastructure (ICER)	0.30	0.30	0.30	-	-
Ocean Observatories Initiative (OCE and ICER)	55.00	55.00	50.00	-5.00	-9.1%
Seismological Facilities for the Advancement of Geosciences and EarthScope (EAR)	24.35	24.35	26.95	2.60	10.7%
U.S. Antarctic Facilities and Logistics (PLR)	193.93	194.14	202.14	8.00	4.1%
U.S. Antarctic Logistical Support (PLR)	67.52	67.52	67.52	-	-

Totals may not add due to rounding.

For detailed information on individual facilities, please see the Facilities chapter.

- Support for the Academic Research Fleet decreases $2.0 million, to a total of $84.80 million, reflecting the ramp-down in planning for the construction of Regional Class Research Vessels as this project transitions to construction supported by the MREFC account.

- Arctic Research Support and Logistics increases $3.0 million, to a total of $ 42.41 million, enabling increased use of marine platforms, such as the newly available *Sikuliaq*, for oceanographic research.

- Arecibo Observatory support remains steady at $4.10 million. The Directorate for Mathematical and Physical Sciences (MPS) leads this activity.

- Support for Geodesy Advancing Geosciences and EarthScope (GAGE) increases $1.50 million, to $13.08 million. This increase is required for the facility to continue supporting the user community at current levels while upgrading instrumentation.

- Funding for the IceCube Neutrino Observatory increases $50,000, to a total of $3.50 million, in support of this facility at the South Pole.

- Funding for the International Ocean Discovery Program (IODP) is maintained at $48.0 million.

- The National Center for Atmospheric Research (NCAR) will increase $1.30 million, to a total of $101.0 million. The increase will allow continued research and service at approximately the FY 2016 level to continue.

- The Ocean Observatories Initiative (OOI) represents a bold step forward in ocean observing for basic research, providing near real-time access to instrumented networks on the sea floor and in the water column at strategic locations around the globe. FY 2016 saw the initiation of full operation of the network, and in FY 2017 will scale back somewhat to $50.0 million (-$5.0 million) as operation and maintenance of OOI assets is competed.

- Support for Seismological Facilities for the Advancement of Geosciences and EarthScope (SAGE) increases $2.60 million, to $26.95 million. This increase is required for the facility to continue supporting the user community at current levels and to upgrade/replace aging infrastructure.

- U.S. Antarctic Facilities and Logistics support increases $8.0 million, to a total of $202.14 million. $5.0 million of this increase will augment the $18.50 million that is annually spent on implementing the Blue Ribbon Panel (BRP) recommendations. Preconstruction planning for the Antarctic Infrastructure Modernization for Science (AIMS) project will be funded at $5.0 million.

Summary and Funding Profile

GEO supports investment in disciplinary and interdisciplinary research and education as well as research infrastructure such as NCAR, the Academic Research Fleet, and research stations in the Arctic and Antarctic.

In FY 2017, the number of research grant proposals is expected to increase above FY 2016 and GEO expects to award about 1,400 research grants. Average annual award size and duration are not expected to materially fluctuate in FY 2015 through FY 2017.

Operations and maintenance funding for GEO-supported user facilities and infrastructure comprises about 52 percent of GEO's FY 2017 Request. GEO has increased operations budgets for some facilities in FY 2017 in order to maintain current operational capacity.

GEO Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	5,814	5,900	6,300
Number of New Awards	1,465	1,500	1,600
Funding Rate	25%	25%	25%
Statistics for Research Grants:			
Number of Research Grant Proposals	5,300	5,600	6,000
Number of Research Grants	1,240	1,300	1,400
Funding Rate	23%	23%	23%
Median Annualized Award Size	$142,954	$145,000	$145,000
Average Annualized Award Size	$183,266	$185,000	$185,000
Average Award Duration, in years	2.7	2.7	2.7

Program Monitoring and Evaluation

Workshops and Reports

- An *ad hoc* committee of members of the geospace science community was charged in January of 2015 to conduct a portfolio review for the geospace sciences in AGS. That committee is expected to deliver a final report with recommendations by February 2016. The report will then be reviewed by the National Academies of Science (NAS) in 2016.

- A Meeting of Experts convened by NAS was held on October 29, 2015 to discuss the NSF Earth Sciences-funded workshop report on *Future Seismic and Geodetic Facility Needs in the Geosciences*.[2] The participants provided individual perspectives on the relative importance of various current and emerging facility capabilities needed to support future Earth Sciences science and research directions. The discussions inform the development of the solicitation to re-compete EAR's geophysical facilities that will be issued in early CY 2016.

- In 2015 two notable reports were received:
  - The NAS completed a study of OCE's research and infrastructure portfolio, *Sea Change: Decadal Survey of Ocean Sciences 2015-2025*.[3] Initiated in FY 2013 and delivered in FY 2015, this study evaluated potential scientific emphases and the infrastructure required to achieve transformative research within these areas. The report provided insight on future scientific research directions, and made specific recommendations regarding OCE infrastructure investment. This report is helping to guide strategic decisions within OCE.
  - The NAS released *A Strategic Vision for NSF Investments in Antarctica and Southern Ocean Research,*[4] identifying opportunities and challenges for Antarctic and Southern Ocean research, and suggesting research priorities for the coming decade. This and prior related reports help shape research directions in the region.

Committees of Visitors (COV)

- In 2015, COV's reviewed OCE's ocean research and education programs, and AGS' NCAR and facilities section. The COV's reports were presented to the Advisory Committee for Geosciences, which convened in April and October of 2015. Reports and GEO responses to them are publically available through the NSF web site.[5]
- In 2016, COVs will review programs in AGS and PLR.
- In 2017, COVs will review programs in EAR, AGS, and OCE.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

[2] www.iris.edu/hq/files/workshops/2015/05/fusg/reports/futures_report_high.pdf
[3] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences
[4] www.nap.edu/catalog/21741/a-strategic-vision-for-nsf-investments-in-antarctic-and-southern-ocean-research
[5] www.nsf.gov/geo/acgeo_cov.jsp

Number of People Involved in GEO Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	5,133	5,200	5,500
Other Professionals	2,776	2,800	3,000
Postdoctoral Associates	594	600	600
Graduate Students	2,505	2,500	2,700
Undergraduate Students	2,243	2,300	2,400
Total Number of People	**13,251**	**13,400**	**14,200**

DIVISION OF ATMOSPHERIC AND GEOSPACE SCIENCE (AGS) $267,920,000 +$14,250,000 / 5.6%

AGS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, AGS	**$252.18**	**$253.67**	**$267.92**	**$14.25**	**5.6%**
Research	**119.56**	**123.73**	**129.58**	**5.85**	**4.7%**
CAREER	5.90	5.04	5.04	-	-
Centers Funding (total)	2.66	-	-	-	N/A
STC: Multiscale Modeling of Atmospheric Processes	2.66	-	-	-	N/A
Education	**6.11**	**2.64**	**2.64**	**-**	**-**
Infrastructure	**126.51**	**127.30**	**135.70**	**8.40**	**6.6%**
NCAR	98.70	99.70	101.00	1.30	1.3%
Arecibo Observatory	4.00	4.10	4.10	-	-
Research Resources	23.81	23.50	30.60	7.10	30.2%

Totals may not add due to rounding.

The FY 2017 Budget Request for AGS is $267.92 million, of which $253.67 million is discretionary funding and $14.25 is new mandatory funding. The mandatory funding is within the Research ($5.85 million), NCAR ($1.30 million) and Research Resources ($7.10 million) lines in the above table.

The mission of AGS is to extend intellectual frontiers in atmospheric and geospace sciences by making responsible investments in fundamental research, technology development, and education that enable discoveries, nurture a vibrant, diverse scientific workforce, and help attain a prosperous and sustainable future. AGS supports activities to further understanding of the dynamics of the sun and the physics, chemistry, and dynamics of the Earth's atmosphere and near-space environment. AGS provides support for: 1) basic science projects and 2) the acquisition, maintenance, and operation of observational and cyber-infrastructure facilities and services that enable and support modern day atmospheric and geospace science research activities. Although the majority of AGS support is through traditional individual investigator merit reviewed, multi-year grants, the division also supports small-scale, limited duration exploratory research projects; collaborative or multi-investigator group projects focusing on a particular project, subject, or activity; large center or center-like projects; and funding for the research conducted at facilities provided by NSF's NCAR, which extends and enhances research at universities. More information on NCAR is available in the Facilities chapter. The division will continue support in key areas of fundamental atmospheric and geospace science, including efforts to improve understanding of the dynamics, predictability, and impacts of extreme atmospheric and space weather events, and development of fundamental knowledge to support predictability and improve adaptation to and resilience with respect to short and long-term variability in weather.

About 26 percent of the AGS portfolio is available to support new research grants. The remainder supports research grants made in prior years and the research infrastructure needed by this community.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Support for the AGS disciplinary and interdisciplinary research programs increases by $5.85 million, to a total of $129.58 million, to support basic research into understanding weather and precipitation variability and extreme atmospheric and space weather phenomena, and improving the fundamentals that lead to better predictability of extreme events.
- AGS will increase support for NSF's INFEWS activity by $1.0 million, to a total of $1.50 million.
- AGS will maintain support the NSF Risk and Resilience initiative at a level of $3.0 million through GEO's PREEVENTS activity.
- Investments in the SEES portfolio decrease by $5.0 million, to $5.0 million, as the SEES Earth Systems Modeling (EaSM) program ramps down.
- Support for early-career researchers remains an AGS priority. The division will maintain support for CAREER grants at $5.04 million.

Education

- Support for education activities across AGS is maintained at $2.64 million, reflecting the division's continuing commitment to the Research Experiences for Undergraduates (REU) program and support for postdoctoral fellows.

Infrastructure

- Funding for the Arecibo Observatory will remain at $4.10 million.
- NCAR support is increased by $1.30 million, to a total of $101.0 million. This increase will support innovation and a one-time revitalization of its infrastructure for advancing the understanding of high-impact atmospheric and space weather hazards.
- Research Resources are allocated $30.60 million, an increase of $7.10 million, to support the development of advanced technologies for high resolution observations of hazardous weather, and space weather events, for improved predictability, and to support data management and accessibility tools needed by the research community.

DIVISION OF EARTH SCIENCES (EAR) $191,680,000 +$12,290,000 / 6.9%

EAR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, EAR	**$178.31**	**$179.39**	**$191.68**	**$12.29**	**6.9%**
Research	**115.86**	**116.46**	**123.65**	**7.19**	**6.2%**
CAREER	6.43	5.58	5.77	0.19	3.4%
Education	**4.49**	**5.00**	**5.00**	**-**	**-**
Infrastructure	**57.96**	**57.93**	**63.03**	**5.10**	**8.8%**
Geodesy Advancing Geosciences and EarthScope (GAGE)	11.58	11.58	13.08	1.50	13.0%
Seismological Facilities for the Advancement of Geosciences and EarthScope (SAGE)	24.35	24.35	26.95	2.60	10.7%
Research Resources	22.03	22.00	23.00	1.00	4.5%

Totals may not add due to rounding.

The FY 2017 Budget Request for EAR is $191.68 million, of which $179.39 million is discretionary funding and $12.29 million is new mandatory funding. The mandatory funding is within the Research ($5.75 million), Education ($1.44 million), GAGE ($1.50 million), SAGE ($2.60 million), and Research Resources ($1.0 million) lines in the above table.

EAR supports fundamental research into the structure, composition, and evolution of the Earth, and the life it has sustained over the four and a half billion years of Earth history. The results of this research will lead to a better understanding of Earth's changing environment (past, present, and future), the natural distribution of its water, food, and energy resources, and provide methods for predicting and mitigating the effects of geologic hazards such as earthquakes, volcanic eruptions, floods, and landslides.

EAR supports research in geomorphology and land use, hydrologic science, geobiology and low temperature geochemistry, sedimentary geology and paleobiology, geophysics, tectonics, petrology and geochemistry, and integrated Earth systems. In addition to these fundamental research programs, EAR has an Instrumentation and Facilities program that supports community-based, shared-use facilities and the acquisition and development of instrumentation by individual investigators; EarthScope, a large-scale facility with an associated science program focused on studying the structure and tectonics of the North American continent; and an education program that funds a number of activities to attract and support students and young investigators to the field of earth science.

About 30 percent of the EAR portfolio is available to support new research grants. The remaining 70 percent supports research grants made in prior years and the research infrastructure needed by this community.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Disciplinary and interdisciplinary research programs in EAR will increase by $7.19 million, to a total of $123.65 million.
- EAR will increase support for INFEWS by $2.0 million, to a total of $3.72 million.
- Support for Risk and Resilience research will be maintained at $4.75 million through GEO's PREEVENTS activity.
- CAREER funding will be supported at a level of $5.77 million, an increase of $190,000, reflecting EAR's continued commitment to supporting early career investigators.

Education

- EAR's support for education activities will be maintained at $5.0 million. Research Experiences for Undergraduates (REU) sites will be supported at $1.52 million, and support for EAR Postdoctoral Fellowships will be funded at $1.73 million, reflecting EAR's commitment to workforce development.

Infrastructure

- EAR will increase investment in SAGE (+$2.60 million, to a total of $26.95 million) and GAGE (+$1.50 million, to a total of $13.08 million), respectively), allowing for replacement and upgrade of key instrumentation to continue to serve growing communities of researchers.
- Increased funding of $1.0 million, to a total of $23.0 million, will enable EAR's Instrumentation and Facilities Program to provide more support for multi-user regional and national facilities.

DIVISION OF INTEGRATIVE AND COLLABORATIVE EDUCATION AND RESEARCH — $94,950,000 +$11,220,000 / 13.4%

ICER Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, ICER	**$84.22**	**$83.74**	**$94.95**	**$11.22**	**13.4%**
Research	**50.99**	**54.24**	**63.33**	**9.09**	**16.8%**
CAREER	0.11	-	-	-	N/A
Education	**18.93**	**15.20**	**14.32**	**-0.88**	**-5.8%**
Infrastructure	**14.30**	**14.30**	**17.30**	**3.00**	**21.0%**
Midscale Research Infrastructure	-	-	10.00	10.00	N/A
National Nanotechnology Coordinated Infrastructure	0.30	0.30	0.30	-	-
Ocean Observatories Initiative	14.00	14.00	7.00	-7.00	-50.0%

Totals may not add due to rounding.

The FY 2017 Budget Request for ICER is $94.95 million, of which $84.77 million is discretionary funding and $10.18 million is new mandatory funding. The mandatory funding is within the Research ($10.18 million) line in the above table.

ICER supports novel, complex, or partnership projects in both research and education. These investments cut across traditional boundaries within the geosciences, encouraging interdisciplinary activities and responding directly to critical needs of the entire geoscience community. ICER's principal goals are to develop innovative means to initiate and support geoscience education, attract underrepresented groups to careers in the geosciences, foster the interchange of scientific information nationally and internationally, and to join with other parts of NSF in major integrative research and education efforts. In FY 2017, the division will make strategic investments in multidisciplinary research areas, international activities, education, diversity, and human resource development.

In general, 43 percent of the ICER portfolio is available for new research grants and the remaining 57 percent supports continuing grants made in previous years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- ICER will continue support for NSF's INFEWS investment at a level of $2.78 million.
- An NSF-wide thrust on Risk and Resilience research will continue to be supported through GEO's PREEVENTS activity at $4.0 million.
- ICER will support activities in SEES totaling $7.0 million in FY 2017, a reduction of $3.0 million, reflecting the phasing out of this activity.
- ICER supports a varied portfolio of international collaborative activities. In FY 2017, this will again total $6.50 million, and emphasize collaborative research across the Americas and activities sponsored by the Belmont Forum, a group of the world's leading and emerging funding agencies focused on providing international, multi-lateral research opportunities for sustainability.

- In FY 2017, ICER will restore investment in large cross-division research projects (+$7.50 million). Last funded through ICER in FY 2014, the division has historically played a key role in facilitating the support of emerging fields across the geosciences.

Education

- In FY 2017, the ICER education portfolio is decreased by $880,000 to $14.32 million. ICER funds most of GEO's NSF-wide education programs.

Infrastructure

- ICER provides GEO's contribution to the National Nanotechnology Coordinated Infrastructure, which is maintained at $300,000.
- In FY 2017, ICER will provide $7.0 million, a decrease of $7.0 million, in support of operation and maintenance for the Ocean Observatories Initiative (OOI). This temporary support, from FY 2015 - FY 2017, helps enable OCE to maintain a robust research enterprise while transitioning its' facilities in response to the National Academy of Sciences' report *Sea Change: Decadal Survey of Ocean Sciences 2015-2025*,[6] released in January, 2015.
- Mid-Scale Infrastructure: Support for this new activity will enable GEO to invest in emerging infrastructure beyond the scope of the MRI program, but smaller than what is typically funded through NSF's MREFC account. Initial GEO funding will be $10.0 million.

[6] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

DIVISION OF OCEAN SCIENCES (OCE) $379,420,000
+$19,530,000 / 5.4%

OCE Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, OCE	**$361.31**	**$359.89**	**$379.42**	**$19.53**	**5.4%**
Research	**173.74**	**175.56**	**193.89**	**18.33**	**10.4%**
CAREER	2.53	2.16	2.16	-	-
Centers Funding (total)	7.66	5.00	5.00	-	-
STC: Coastal Margin Observation and Prediction	2.66	-	-	-	N/A
STC: Dark Energy Biosphere Investigations	5.00	5.00	5.00	-	-
Education	**5.25**	**2.73**	**2.73**	**-**	**-**
Infrastructure	**182.32**	**181.60**	**182.80**	**1.20**	**0.7%**
Academic Research Fleet	79.87	83.80	82.80	-1.00	-1.2%
International Ocean Discovery Program (IODP)	48.00	48.00	48.00	-	-
Ocean Observatories Initiative (OOI)	41.00	41.00	43.00	2.00	4.9%
Research Resources	11.32	5.80	7.00	1.20	20.7%
Facilities Pre-Construction Planning (total)	2.13	3.00	2.00	-1.00	-33.3%
Regional Class Research Vessels (RCRV)	2.13	3.00	2.00	-1.00	-33.3%

Totals may not add due to rounding.

The FY 2017 Budget Request for OCE is $379.42 million, of which $359.89 million is discretionary funding and $19.53 million is new mandatory funding. The mandatory funding is within the Research ($18.33 million) and Research Resources ($1.20 million) lines in the above table.

OCE supports interdisciplinary research, education, and cutting edge infrastructure that advances our scientific knowledge of the oceans to support the U.S. economy over the long term, provide vital information regarding national security matters such as sea level rise, and to advance U.S. leadership in ocean science. OCE provides support of basic scientific research to better understand changing ocean circulation and other physical parameters, biodiversity and the dynamics of marine organisms and ecosystems, and changing ocean chemistry as exemplified by ocean acidification. OCE also supports research on the geology of the ocean margins and sub-seafloor to investigate the stability of methane hydrates, natural hazards associated with earthquakes and volcanic eruptions, microbial life deep below the seafloor, and other fundamental ocean processes. Ocean education emphasizes undergraduate REU programs and the interdisciplinary nature of ocean sciences, and commonly leverages off research facilities and infrastructure via telepresence to far and distant seas. Since ocean science requires access to the sea, OCE supports research vessels, deep submergence capability including submersibles and autonomous vehicles, and technologically advanced sensors and instrumentation. Broadly speaking, research, education, and infrastructure funded by OCE addresses the central role of the oceans in a changing Earth and as a national strategic resource, as recognized by numerous reviews by external bodies (e.g., National Academy of Sciences), as well as in the President's 2010 Executive Order 13547 establishing a National Ocean Policy (NOP) and creating a National Ocean Council (NOC).[7]

[7] Executive Order 13547 – Stewardship of the Ocean, Our Coasts, and the Great Lakes. July 19, 2010. www.whitehouse.gov/the-press-office/executive-order-stewardship-ocean-our-coasts-and-great-lakes

In FY 2017, research emphases in OCE will continue to be guided by *Science for an Ocean Nation: Update of the Ocean Research Priorities Plan*, [8] which was published by the NSTC Subcommittee on Ocean Science and Technology (SOST) in 2013. This report identifies national research priorities in key areas of interaction between society and the ocean. These priorities include improved understanding of marine ecosystems, marine biodiversity, the impact of increased atmospheric carbon dioxide on ocean acidification, ocean observing, changing conditions in the Arctic, hazards and extreme events, and the enhancement of infrastructure to support ocean and coastal research. Specifically for FY 2017, OCE's budget reflects steps forward to a re-alignment of the balance between research and technology funding and support for large infrastructure, as per the suite of recommendations made by the National Research Council/National Academy of Sciences' highly influential report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*.[9]

In general, 32 percent of the OCE portfolio is available for new research grants in basic science and technological innovation. The remaining 68 percent supports the major research infrastructure of the Academic Research Fleet, the International Ocean Discovery Program, and the Ocean Observatories Initiative, and supports awards made in prior years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>

- OCE's budget for disciplinary and interdisciplinary research will increase by $17.08 million, to a total of $174.50 million, which reflects bolstering ocean science research programs as per *Sea Change* recommendations, and also through specific investment in studying ocean-based mechanisms active along the land/ocean interface (e.g., sea level change over local, regional, and global scales).
- In FY 2017, OCE will support the Long-Term Ecological Research (LTER) program at a level of $5.75 million (+$1.0 million) to accommodate at least one new coastal location.
- OCE will continue support at $5.0 million for the NSF-wide thrust on Risk and Resilience research through the PREEVENTS activity.

<u>Education</u>

- There is no change in OCE support ($2.73 million) for REU programs or other interdisciplinary education efforts.

<u>Infrastructure</u>

- OCE is decreasing support of ship operations within the Academic Research Fleet by $1.0 million, to a level of $82.80 million, due to the decrease in overall number of vessels and efficiencies gained by technological investment. This decrease is consistent with the recommendations from *Sea Change*. OCE will continue to support the planned development of Regional Class Research Vessels (RCRVs) at $2.0 million (- $1.0 million), which is consistent with long-term planning needs.
- Funding is requested for continued support for operations of the drilling vessel, *JOIDES Resolution*, as part of the U.S. contribution to the IODP. The FY 2017 Request of $48.0 million maintains level funding with no decrease in operations.
- Support for operations and maintenance of the Ocean Observatories Initiative (OOI) will be increased $2.0 million, to $43.0 million. This will be supplemented by $7.0 million from ICER, bringing the total operations and maintenance for OOI to $50.0 million, which is an overall decrease of $5.0 million. This is consistent with the recommendations from *Sea Change*.

[8] www.whitehouse.gov/sites/default/files/microsites/ostp/ocean_research_plan_2013.pdf
[9] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

DIVISION OF POLAR PROGRAMS (PLR) $464,860,000 +$23,010,000 / 5.2%

PLR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, PLR	**$443.02**	**$441.85**	**$464.86**	**$23.01**	**5.2%**
Research	**111.30**	**128.00**	**139.82**	**11.82**	**9.2%**
CAREER	1.21	1.03	1.03	-	-
Education	**3.37**	**2.71**	**2.35**	**-0.36**	**-13.3%**
Infrastructure	**328.35**	**311.14**	**322.69**	**11.55**	**3.7%**
Arctic Research Support and Logistics	56.52	39.41	42.41	3.00	7.6%
IceCube Neutrino Observatory (IceCube)	3.45	3.45	3.50	0.05	1.4%
U.S. Antarctic Facilities and Logistics	194.20	194.14	202.14	8.00	4.1%
U.S. Antarctic Logistical Support	67.52	67.52	67.52	-	-
Polar Environment, Safety, and Health (PESH)	6.66	6.62	7.12	0.50	7.6%
Facilities Pre-Construction Planning	3.70	14.50	5.00	-9.50	-65.5%

Totals may not add due to rounding.

The FY 2017 Budget Request for PLR is $464.86 million, of which $441.84 million is discretionary funding and $23.02 million is new mandatory funding. The mandatory funding is within the Research ($11.52 million), Arctic Research Support and Logistics ($3.0 million), Antarctic Facilitates and Logistics ($8.0 million), and Polar Environment, Safety, and Health ($500,000) lines in the above table.

The Division of Polar Programs (PLR) provides interagency leadership and is the primary U.S. supporter of research in the polar regions. Arctic Sciences supports research in social, earth systems, and a broad range of natural sciences; its' Research Support and Logistics program responds to research by assisting researchers with access to the Arctic and the planning and sharing of results with local Arctic communities. Antarctic Sciences funds research in a broad range of areas for which access to Antarctica and/or the Southern Ocean is essential to advancing the scientific frontiers. Antarctic Facilities and Logistics enables research in Antarctica on behalf of the U.S. government through a network of stations, labs, equipment, and logistical resources. The Polar Environment, Safety, and Health (PESH) section provides oversight for the environmental, safety, and health aspects of research and operations conducted in polar regions.

PLR's FY 2017 Request reflects three key priorities: (1) maintaining strong disciplinary programs that provide a basis for investments in cross-disciplinary science programs; (2) focusing basic research on cross-foundation (e.g., INFEWS, PREEVENTS) and interagency priorities; and (3) supporting and improving the efficiency of critical facilities that enable research in both polar regions. For Antarctica, the primary objective is to continue progress on a multi-year commitment toward more efficient and cost-effective science support as recommended by the U.S. Antarctic Program (USAP) Blue Ribbon Panel (BRP) report, *More and Better Science in Antarctica through Increased Logistical Effectiveness*.[10] NSF issued a formal response to this report in March 2013.[11] Emphases include safety and health improvements, investments with positive net present value, and facilities renewal at McMurdo and Palmer stations. Additionally, the Antarctic sciences community is planning for the more effective observational approaches and science

[10] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp
[11] www.nsf.gov/news/news_summ.jsp?cntn_id=127345&org=NSF&from=news

priorities that were respectively outlined in 2011 and 2015 NRC reports; *Future Science Opportunities in Antarctica and the Southern Ocean*[12] and *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research.*[13] For the Arctic, shared cross-directorate basic research objectives, the Interagency Arctic Research Policy Committee's (IARPC) *Arctic Research Plan: FY 2013-2017,*[14] and the *National Ocean Policy Implementation Strategy*[15] inform science investment priorities.

PLR funds both research and the necessary research support in the form of logistics and infrastructure. About 13 percent of PLR's funds are available for new research grants each year. The supporting logistics and infrastructure budget is 70 percent of overall funds, with the remainder supporting research awards made in prior years.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Funding for research increases by $11.82 million, to a total of $139.82 million.
- Approximately $8.52 million of the increase is directed toward land/ocean/ice interface and sea level change, including related critical supporting science infrastructure.
- An investment of $1.0 million in the cross-directorate INFEWS activity will fund research for understanding the mechanisms that enable sustainability and resiliency of global water, food, and energy resources.
- A continued investment of $1.0 million will fund polar research efforts contributing to the cross-directorate Risk and Resilience emphasis area through the PREEVENTS program.
- Research funding dedicated to SEES will decrease (-$1.50 million), to a total of $1.50 million, as focus areas related to earth systems modeling and Arctic sustainability end.

Education

- Funding decreases (-$360,000) to a total of $2.35 million, due to the end of funding for IGERT commitments.

Infrastructure

- Arctic Research Support and Logistics: This program provides support for Arctic researchers, including access to airplanes, helicopters, research vessels including icebreakers, and field camps for approximately 150 projects in remote sites in Alaska, Greenland, Canada, Arctic Scandinavia, Russia, and the Arctic Ocean. Summit Station on the Greenland ice cap operates as a year-round international site for a variety of atmospheric and geophysical measurements. An increase (+$3.0 million) to a total of $42.41 million, enables increased use of marine platforms, such as the newly available *Sikuliaq*, for oceanographic research.
- IceCube Neutrino Observatory: PLR continues to match the MPS contribution, at $3.50 million, that includes an increase of $50,000 in FY 2017 for operation and maintenance.
- U.S. Antarctic Facilities and Logistics: Funding provides all necessary infrastructure, instrumentation, and logistics for scientists from all disciplines and all U.S. agencies performing research in Antarctica. This support includes forward staging facilities in New Zealand and South America; operation of three year-round stations in Antarctica; Department of Defense fixed-wing aircraft, contracted rotary- and fixed-wing aircraft; two leased research vessels; and icebreaking services from the U.S. Coast Guard

[12] www.nap.edu/catalog.php?record_id=13169
[13] www.nap.edu/catalog/21741/a-strategic-vision-for-nsf-investments-in-antarctic-and-southern-ocean-research
[14] www.nsf.gov/od/opp/arctic/iarpc/arc_res_plan_index.jsp
[15] www.whitehouse.gov/administration/eop/oceans/implementationplan

in support of annual resupply efforts. This budget request of $202.14 million includes an $8.0 million increase. Approximately $23.50 million (+$5.0 million) will be spent on implementing the BRP recommendations, allowing for timely replacement of the Ross Island ground station that is critical for weather and other satellite data transfer. Within this amount, $5.0 million is for advancing the Antarctic Infrastructure Modernization for Science (AIMS) project to redevelop McMurdo Station toward Preliminary Design Review. This comprehensive redevelopment of McMurdo involves replacement and reconfiguration of core science, operations, and logistics support facilities for more efficient and effective support of Antarctic science.

- Polar Environment, Safety and Health: Funding is provided for implementation of both environmental protection and environmental stewardship to minimize the environmental impact of PLR-supported activities in polar regions, as well as programs to ensure the safety and health of participants in Antarctica, and certain Arctic operating locations. An increase of $50,000, to a total of $7.12 million, permits development of a suite of web-based tools for managing the secure transfer of polar participants' medical information and environmental permitting and reporting that is required for compliance with the Antarctic Treaty and U.S. implementing legislation.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS) $1,436,450,000 +$87,300,000 / 6.5%

MPS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Astronomical Sciences (AST)	$245.23	$246.73	$262.61	$15.88	6.4%
Chemistry (CHE)	246.29	246.31	262.16	15.85	6.4%
Materials Research (DMR)	337.62	310.03	329.71	19.68	6.3%
Mathematical Sciences (DMS)	235.43	234.05	249.17	15.12	6.5%
Physics (PHY)	276.10	277.03	295.26	18.23	6.6%
Office of Multidisciplinary Activities (OMA)	35.65	35.00	37.54	2.54	7.3%
Total, MPS	**$1,376.32**	**$1,349.15**	**$1,436.45**	**$87.30**	**6.5%**

Totals may not add due to rounding.

The FY 2017 Budget Request for MPS is $1,436.45 million, of which $1,355.06 million is discretionary funding and $81.39 is new mandatory funding. The major focus of the mandatory funding is support for core activities, with special emphasis on supporting investigators in the early parts of their careers. These early career investigators bring innovative research ideas that often draw on new possibilities in computational- and data-intensive techniques.

Examples of research areas in which MPS has particular opportunities to support early career scientists and advance computational- and data-intensive research are:

- Quantum Information Science
- Optics and Photonics
- Clean Energy

Each of these areas provides tremendous intellectual opportunities for early career scientists.

About MPS

MPS serves the Nation by supporting fundamental discoveries at the forefront of science. These discoveries form a tapestry of knowledge and innovation that transforms the future. The FY 2017 Request for MPS supports a collection of vigorous disciplinary and multidisciplinary research programs that foster discovery and cultivate the technical workforce. The research programs in MPS provide the foundation of basic research in astronomical sciences (AST), chemistry (CHE), materials research (DMR), mathematical sciences (DMS), and physics (PHY) that explore the frontiers of science.

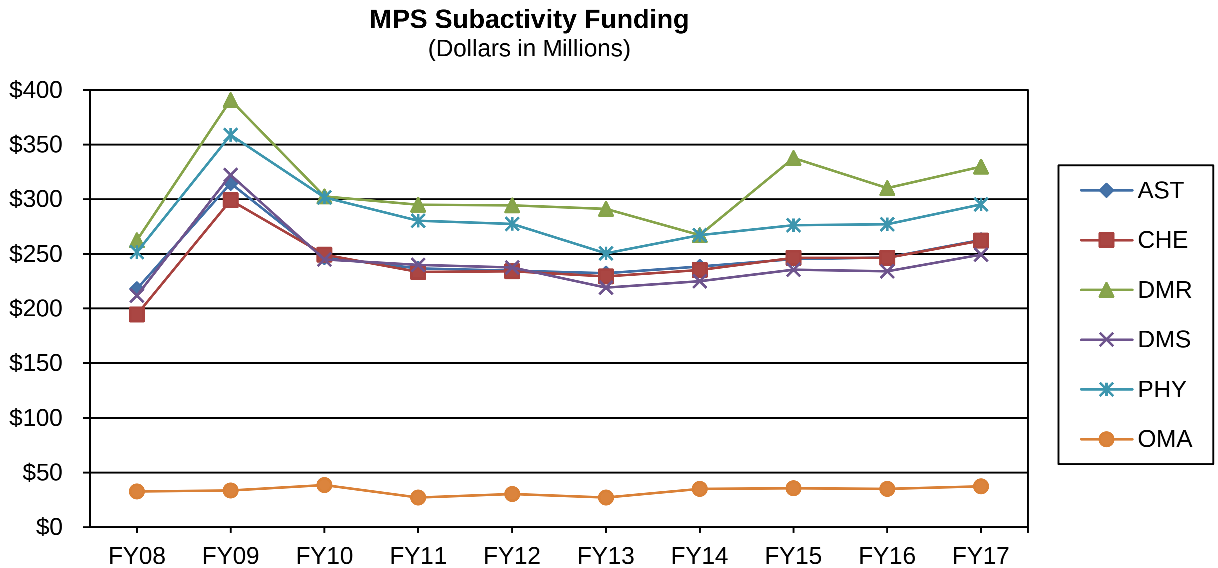
The collection of programs in MPS spans the range from individual investigator awards to large, multi-user facilities. The science spans an enormous range as well: from the smallest objects and shortest times ever studied to distances and times that are the size and age of the universe. Individual investigators and small teams receive the majority of awards, but centers, institutes, and multi-user facilities are all integral to MPS-funded research. The relatively new MPS midscale research infrastructure program is meeting a critical research need, and the FY 2017 Request continues to sustain that effort. MPS is also growing research in optics and photonics, a promising area with well-articulated and exciting possibilities, and in the related area of quantum information science, an activity that links in part to the National Strategic Computing Initiative (NSCI).

Programs in the MPS divisions respond to special intellectual opportunities and reflect careful choices about directions in order to provide the greatest return on the research investment. Identifying these opportunities involves the community through the MPS Advisory Committee and through groups chartered to identify prospects for revolutionary science in particular areas. The Particle Physics Project Planning Panel (P5) Report and the Long Range Plan from the Nuclear Science Advisory Committee are just two recent examples. These and other thoughtful reports inform the choices made in MPS, and the advice the directorate receives often emphasizes our declining support of unsolicited proposals, a source that many regard as the origin of the most vibrant ideas. Thus, supporting unsolicited proposals that address topics central to MPS research is one of our primary goals.

Facilities that enable unique science that would be impossible without the special resources of a shared, multi-user environment are integral to our mission. Some of these facilities are observatories for photons, neutrinos, or gravitational waves. Others provide unique resources such as the largest controlled magnetic fields in the world or beams of rare isotopes. Stewardship of the MPS facilities portfolio and the balance among the different awards programs are critical issues that also engender extensive community consultation. MPS continues assessing the future of different facilities and fostering partnerships for those facilities.

MPS continues to participate in NSF-wide investments and multi-directorate activities, particularly ones that connect to the fundamental research at the heart of its mission. The MPS program in optics and photonics is a partnership with the Directorates for Engineering (ENG) and Computer and Information Science and Engineering (CISE). Investments continue in NSF-wide investments such as Research at the Interface of the Biological, Mathematical, and Physical Sciences (BioMaPS); Understanding the Brain (UtB); Cyber-Enabled Materials Manufacturing and Smart Systems (CEMMSS), which includes both advanced manufacturing and Designing Materials to Revolutionize and Engineer the Future (DMREF); Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21); Secure and Trustworthy Cyberspace (SaTC); and NSF Innovation Corps (I-Corps™). Core research funds also contribute to research in clean energy technology and support the program of Research Experiences for Undergraduates (REU). The Sustainable Chemistry, Engineering, and Materials (SusChEM) program is also part of this Request and will continue to evolve even as the NSF-wide investment in Science, Engineering, and Education for Sustainability (SEES) concludes at the end of FY 2017.

MPS provides about 43 percent of the federal funding for basic research at academic institutions in the mathematical and physical disciplines covered by MPS.



FY 2009 funding reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- AST's FY 2017 Request will support individual investigator awards and astronomical observatories, as well as investment in CIF21 and the major MPS priority of midscale research infrastructure. Funding for individual investigator research is balanced against funding for facilities. Among facilities, support for the Daniel K. Inouye Solar Telescope (DKIST) increases.

- CHE's FY 2017 Request provides enhanced support for core research programs and augments the focus on Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) as a research driver. CHE will continue its commitment to research in clean energy technologies, advanced manufacturing, and CIF21. CHE also strongly supports research at the interfaces of biology and chemical science, within both experimental and theoretical/computational frameworks, including the major cross-Foundation effort, UtB.

- DMR's FY 2017 Request provides continued support for its portfolio of individual investigators, small teams, and centers, especially in areas where advanced materials are essential for areas such as advanced manufacturing, CEMMSS (through DMREF), clean energy technologies, sustainability, and UtB. DMR will continue to support its facilities, including the newly launched Materials Innovation Platforms (MIP) program as investment in mid-scale research infrastructure.

- DMS's FY 2017 Request focuses on enhancing support for frontier research, training a diverse group of researchers in mathematical and statistical sciences with computational skills, investing in mathematical sciences institutes, and providing support through efficient mechanisms to foster multidisciplinary research activities in, but not limited to CIF21, Risk and Resilience, BioMaPS, CEMMSS, SaTC, and UtB.

- PHY's FY 2017 Request includes continued support for individual investigator awards, particularly those in NSF-wide priorities such as CIF21, BioMaPS, and UtB. PHY also requests increased funding for investigators using its major facilities, and for operations and maintenance of these facilities. In

FY 2017, PHY will maintain its program in accelerator science and its commitment to the MPS priority of midscale research infrastructure.

- OMA will continue its role of providing support for multidisciplinary research and activities in education and broadening participation. OMA will emphasize research relevant to NSF priorities such as CIF21, BioMaPS, UtB, and CEMMSS. OMA will coordinate MPS activities related to I-Corps™, NSF Research Traineeship (NRT), and NSF-wide Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES). Also OMA will support responsible decisions regarding portfolio composition, including studies of possible environmental issues, stewardship transition costs, or partnership start-up costs; in FY 2017, the focus will be on implementing the recommendations of the AST portfolio review.

Major Investments

MPS Major Investments
(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
BioMaPS	$17.94	$13.00	$13.00	-	-
CAREER	79.07	67.53	68.45	0.92	1.4%
CEMMSS	65.07	49.84	47.14	-2.70	-5.4%
Advanced Manufacturing	*65.07*	*49.84*	*47.14*	*-2.70*	*-5.4%*
Clean Energy Technology	123.23	143.34	195.36	52.02	36.3%
CIF21	34.89	11.50	16.15	4.65	40.4%
NSF I-Corps™	1.30	1.70	1.70	-	-
NSF INCLUDES	-	2.74	2.60	-0.14	-5.1%
INFEWS	-	2.40	6.40	4.00	166.7%
NRT[1]	5.04	4.47	4.54	0.07	1.6%
Risk and Resilience	-	0.50	0.50	-	-
SaTC	1.86	2.00	2.00	-	-
SEES	50.85	16.00	13.00	-3.00	-18.8%
Understanding the Brain	15.44	19.49	18.70	-0.79	-4.1%
BRAIN Initiative	15.44	19.49	18.70	-0.79	-4.1%

Major investments may have funding overlap and thus should not be summed.

[1] Outyear cmmitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $2.80 million in FY 2015 and $220,000 in FY 2016.

- BioMaPS (equal to the FY 2016 Estimate at $13.0 million): This continues to be an exciting research area, the focus of which is the partnership with BIO that will emphasize research towards Understanding the Brain (UtB) and other emerging areas of multidisciplinary science.

- CAREER (+$920,000, to a total of $68.45 million): This program remains a top priority for the directorate, ensuring that top young scientists in all of the MPS disciplines are funded at a healthy level. The CAREER program is an important element in the growth and maturity of young scientists.

- Cyber-Enabled Materials Manufacturing and Smart Systems (CEMMSS) (-$2.70 million below the FY 2016 Estimate): MPS' contribution includes both Advanced Manufacturing and Designing Materials to Revolutionize and Engineer the Future (DMREF). DMREF is the MPS response to the Administration's Materials Genome Initiative and has received strong interest from MPS communities. MPS will continue to support highly meritorious proposals to advance materials discovery by closely linking theory, modeling, and experiment, an approach critical to solving related research challenges in areas such as optics and photonics, clean energy, and the brain.

- Clean Energy Technology (+$52.02 million, to a total of $195.36 million): Research in this area remains strong in MPS core programs.

- MPS's Computational and Data-Enabled Science and Engineering (CDS&E) program, which is part of CIF21, supports development of fundamental insights in materials and physics that will carry computation beyond the limits of current technology as well as creating algorithms and software for new approaches to computation and data analytics. An increase of $4.65 million in FY 2017 (to a total of $16.15 million) will support the evolution of these efforts as CIF21 concludes as planned. Funding will also support activities at the heart of the new federal government-wide National Strategic Computing Initiative (NSCI), which MPS and the Directorate for Computer and Information Science and Engineering (CISE) will lead within NSF.

- I-Corps™ (level with FY 2016 Estimate at $1.70 million): MPS support in this area continues, primarily through I-Corps™ teams. Investments are directed to an assessment of the commercial viability of the scientific discoveries in MPS disciplines through the individual investigator award program.

- NSF INCLUDES (-$140,000 to $2.60 million): MPS continues to support the program, an NSF-wide broadening participation activity.

- INFEWS (+$4.0 million, to a total of $6.40 million): This funding provides for cross directorate cooperation and further development of research communities to address sustainability issues.

- NRT: Funding increases (+$290,000, to a total of $4.54 million) while final commitments within the Integrative Graduate Education and Research (IGERT) program (-$220,000 to zero) were completed in FY 2016.

- Risk and Resilience (level at $500,000): MPS will join CISE, ENG, GEO, and SBE in continuing to fund programs within this portfolio. Scientific research supported by MPS will improve predictive and risk-assessment capabilities, increasing resilience to reduce the impact on civilization of extreme events. Work on fundamental scientific issues, such as understanding the dynamic processes that produce extreme events, will advance knowledge and help to create tools for increased resilience of societal infrastructure to natural and anthropogenic hazards.

- SaTC (level at $2.0 million): Funding supports questions surrounding securing information networks against hostile intrusion and ensuring individual privacy in anonymized data sets present crucial challenges for society. Research supported by DMS through SaTC will provide a fresh look at such current cybersecurity challenges from the viewpoint of the mathematical sciences.

- SEES (-$3.0 million, to a total of $13.0 million): Support for SEES concludes at the end of FY 2017 as planned. Much of the remaining funding in MPS will focus on Sustainable Chemistry, Engineering, and Materials (SusChEM) research.

MPS Funding for Centers Programs and Facilities

MPS Funding for Centers Programs
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, Centers Programs	**$123.66**	**$88.89**	**$90.40**	**$1.51**	**1.7%**
Centers for Analysis & Synthesis (DMS)	0.20	0.20	0.20	-	-
Centers for Chemical Innovation (CHE)	36.66	28.10	29.50	1.40	5.0%
Materials Centers (DMR)[1]	79.66	56.00	56.00	-	-
Nanoscale Science & Engineering Centers (CHE, DMR)	0.50	0.50	0.50	-	-
Science & Techology Centers (DMR)	6.64	4.09	4.20	0.11	2.7%

Totals may not add due to rounding.

[1] Due to delayed awards processing, funding for FY 2015 includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- Centers for Chemical Innovation (CCI) (+$1.40 million, to a total of $29.50 million): Funding is expected to support nine Phase II centers and up to three Phase I awards selected in a new competition planned for FY 2017. Total funding required for these centers is $41.40 million, depending on final number of awards made. Of this total, $29.50 million is provided in this Request. The remaining amount is expected to be provided via forward funding from prior fiscal years, co-funding by MPS/OMA, and support from the National Aeronautics and Space Administration (NASA) through an ongoing interagency agreement.

- Materials Research Science and Engineering Centers (MRSEC) ($56.0 million, no change from the FY 2016 Estimate): Funding will support approximately 20 MRSECs, with the precise number depending on the outcome of the next MRSEC competition in FY 2017.

- Nanoscale Science and Engineering Centers (level at $500,000): MPS continues to provide limited support to nanoscale-related centers as this centers program winds down as planned across NSF.

- Science and Technology Center (STC) Center for Integrated Quantum Materials (+$110,000, to a total of $4.20 million): DMR support will ramp up as planned for this STC from the FY 2013 cohort.

MPS Funding for Facilities
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Facilities	**$279.42**	**$269.50**	**$294.58**	**$25.08**	**9.3%**
Arecibo Observatory	4.01	4.10	4.20	0.10	2.4%
Atacama Large Millimeter Array (ALMA)	40.17	40.35	43.25	2.90	7.2%
Cornell High Energy Synchrotron Source (CHESS)[1]	11.97	8.03	10.00	1.97	24.5%
Daniel K. Inouye Solar Telescope (DKIST)	7.00	11.00	16.00	5.00	45.5%
Gemini Observatory	20.61	19.88	20.42	0.54	2.7%
IceCube Neutrino Observatory (IceCube)	3.45	3.45	3.50	0.05	1.4%
Large Hadron Collider (LHC)	18.00	18.00	20.50	2.50	13.9%
Laser-Interferometer Gravitational Wave Observatory (LIGO)	33.00	39.43	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)[2]	35.92	22.78	35.78	13.00	57.1%
National Nanotechnology Coordinated Infrastructure (NNCI)	2.88	2.88	2.88	-	-
National Optical Astronomy Observatories (NOAO)	25.50	21.60	21.83	0.23	1.1%
National Radio Astronomy Observatories (NRAO)[3]	43.14	41.73	32.00	-9.73	-23.3%
National Solar Observatory (NSO)[4]	8.00	9.50	6.00	-3.50	-36.8%
National Superconducting Cyclotron Laboratory (NSCL)	23.00	24.00	24.50	0.50	2.1%
Center for High Resolution Neutron Scattering (CHRNS)	2.77	2.77	2.79	0.02	0.7%
Other Astronomical Facilities[3]	-	-	11.50	11.50	N/A

Totals may not add due to rounding.

[1] Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[2] Forward funding of $11.88 million ($10.0 million from DMR and $1.88 million from CHE) in FY 2015 reduced the amount required in FY 2016.

[3] The decrease in NRAO support is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now under the "Other Astronomical Facilities" line in this table.

[4] Totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $11.50 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented in the DKIST line above.

For detailed information on individual facilities, please see the Facilities chapter.

MPS sustains or increases operations and maintenance budget levels for most of its large user facilities:

- Arecibo Observatory (+$100,000, to a total of $4.20 million): This increase covers added operating costs due to inflation. This value may change in FY 2016 depending on discussions with NSF/GEO and NASA as well as a baseline environmental survey.

- Atacama Large Millimeter Array (ALMA) (+$2.90 million, to a total of $43.25 million): Funding includes an increase of the annual contribution to the ALMA Development Fund agreed to by the international partners.

- Cornell High Energy Synchrotron Source (CHESS) (+$1.97 million, to a total of $10.0 million): MPS funding will support this national user facility of high-energy X rays, which serves researchers in fields of biology, engineering, and materials. In FY 2015, DMR forward funded CHESS by $1.97 million, reducing the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement. (ENG and BIO contributions remain level at $5.0 million each.)

- Daniel K. Inouye Solar Telescope (DKIST) (+$5.0 million, to a total of $16.0 million): This increase supports the continued ramp-up of DKIST operations within NSO from $9.0 million to $11.50 million, plus the DKIST cultural mitigation award held steady at $2.0 million. Of the $16.0 million total, $2.50 million will be used to support the construction of the Remote Operations Building. See the Major Research Equipment and Facilities Construction chapter for more detail.

- Gemini Observatory (+$540,000, to a total of $20.42 million): This level accounts for slight increases in operations and maintenance and in the instrument development fund as agreed to by the international Gemini Board.

- Large Hadron Collider (LHC) (+$2.50 million, to a total of $20.5 million): This level includes $18.0 million for operations and maintenance and $2.50 million for planning a potential Phase II LHC upgrade.

- National High Magnetic Field Laboratory (+$13.0 million, to a total of $35.78 million): This unique facility, using extremely high magnetic fields, enables transformative research in fields ranging from biology and chemistry, to materials and condensed matter physics. Forward funding of $11.88 million ($10.0 million from DMR and $1.88 million from CHE) in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement.

- National Optical Astronomy Observatory (NOAO) (+$230,000, to a total of $21.83 million): This change includes an increase in the NOAO base (+$530,000 to a total of $18.03 million) and a decrease for special projects in partnership with NASA and Department of Energy (DOE) (-$300,000 to a total of $3.80 million).

- National Radio Astronomy Observatories (-$9.73 million, to a total of $32.0 million): This decrease is due to the removal of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the new NRAO cooperative agreement, expected in early FY 2017. GBO and VLBA funding is now captured under Other Astronomical Facilities line described below.

- National Solar Observatory (-$3.50 million, to a total of $6.0 million): Of the total change, most (-$2.50 million to zero) is due to the end of a one-time activity to make NSO Space Weather infrastructure more robust, and the rest (-$1.0 million, to a total of $6.0 million) is a decrease in NSO base support as emphasis shifts to DKIST operations.

- National Superconducting Cyclotron Laboratory (+$500,000, to a total of $24.50 million): Increased funding is pursuant to recent external site reviews that provided updated guidance on management and operations costs for the laboratory.

- Center for High Resolution Neutron Scattering (CHRNS) (+$20,000, to a total of $2.79 million): This small increase will support small (less than three percent) cost of living salary adjustments for CHRNS staff, postdocs, and technicians.

- Other Astronomical Facilities (+$11.50 million, to a total of $11.50 million): This funding is due to the removal of GBO and VLBA from the new NRAO cooperative agreement. See the NRAO bullet above.

Summary and Funding Profile

MPS supports core research, education, and research infrastructure. MPS will invest heavily in areas such as INFEWS, advanced manufacturing, CIF21, clean energy, and UtB, while increasing support for core research areas as well. Midscale instrumentation in several MPS divisions will be maintained in response to community needs.

In FY 2017, the number of research grant proposals to MPS is expected to increase relative to FY 2016, with research grant award funding rates expected to rise as a function of higher budgets.

In FY 2017, MPS will invest $90.40 million for Centers, about 6.3 percent of the FY 2017 Request. This ratio is similar to the FY 2016 Estimate. Centers are an important modality for MPS sciences as research in many MPS-supported disciplines, especially CHE and DMR, has evolved to be more collaborative and interdisciplinary.

Operations and maintenance funding for MPS-supported user facilities comprises almost 21 percent of the FY 2017 Request. Funding is maintained for most facilities in order to keep operational capacity current.

MPS Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	9,133	9,200	9,300
Number of New Awards	2,593	2,600	2,800
Funding Rate	28%	28%	30%
Statistics for Research Grants:			
Number of Research Grant Proposals	8,061	8,100	8,200
Number of Research Grants	2,050	2,100	2,300
Funding Rate	25%	26%	28%
Median Annualized Award Size	$124,932	$125,000	$150,000
Average Annualized Award Size	$148,606	$149,000	$149,100
Average Award Duration, in years	3.1	3.1	3.1

Program Monitoring and Evaluation

<u>External Program Evaluations and Studies</u>

- The MPS Advisory Committee (MPSAC) released a report in 2015, *Response to strategic plan for the Particle Physics Project Prioritization Panel*”[1] which provided a review of existing programs and suggested recommendations for balanced future plans for investments in particle physics.
- The Astronomy and Astrophysics Advisory Committee (AAAC) completed their annual report[2] on interagency activities by DOE, NASA, and NSF in March 2015. The next annual report is expected in March 2016.
- The National Research Council (NRC) of the National Academy of Sciences was commissioned to carry out a study of *A Strategy to Optimize the U.S. Optical/Infrared System in the Era of the Large*

[1] www.nsf.gov/mps/advisory/mpsac_other_reports_chron.jsp
[2] www.nsf.gov/mps/ast/aaac.jsp

Synoptic Survey Telescope.[3] Under the auspices of the NRC Committee on Astronomy and Astrophysics, the study was completed in May 2015. AST delivered an initial public response, including its proposed actions, in Dear Colleague Letter NSF 15-115[4] released in September 2015. Further details on the status of the response were reported to the American Astronomical Society at its January 2016 meeting. NSF continues to work with its awardee for NOAO and the Large Synoptic Survey Telescope (LSST) to refine and update the responses, which will be reported to the community at a variety of forums.

- AST continues to respond to the 2010 decadal survey in astronomy and astrophysics carried out under the auspices of the National Research Council. A recent update on the status of this response was published as Dear Colleague Letter NSF 15-044[5] in March 2015. This letter also included the status of the AST response to the AST Portfolio Review that was carried out by a subcommittee of the Advisory Committee for MPS in 2011-2012.
- AST, together with the NASA Astrophysics Division and the High Energy Physics Branch of the DOE Office of Science, has commissioned study of the mid-term status of agency responses to the 2010 decadal survey in astronomy and astrophysics, through the NRC Space Studies Board. The resulting NRC mid-term review committee will meet three times in early FY 2016 with a final report expected in May 2016.
- In FY 2017, CHE will initiate an evaluation of the Centers for Chemical Innovation (CCI) program. Results are expected to be used to inform the design of future solicitations and center oversight. Final results are expected in FY 2019.
- DMS implemented recommendations of the 2013 report *The Mathematical Sciences in 2025*[6] by the Board on Mathematical Sciences and their Applications of the National Research Council. In response, DMS instituted the new Mathematical Sciences Innovation Incubator (MSII) activity.[7]
- NSF and DOE received a report[8] in October 2015 from the Nuclear Science Advisory Committee (NSAC) that provides a strategic plan for nuclear physics covering the next 10 years.
- NSF and DOE received a report[9] in October 2015 from a subcommittee of NSAC that was charged with providing additional guidance toward a next-generation detector of neutrino-less nuclear double beta decay.

<u>Workshops and Reports</u>

- To identify opportunities for chemical sciences to contribute to solving grand challenges at the nexus of food-energy-water systems, CHE sponsored the following series of workshops:
  - *Enabling Resiliency in Energy Water and Food Systems for Society: Addressing the Scientific, Technological and Societal Challenges of the Energy, Water and Food Nexus*, was held in April of 2015. The final report was published in 2015.[10]
  - *Closing the Human Phosphorous Cycle Workshop* covered chemical advances necessary for efficient use and recovery of the element, phosphorous. The workshop was held in June 2015 and the final report published.[11]
  - *FEWS: Food-Energy-Water Systems Challenging Chemists in the 21st Century* examined grand challenges related to water chemistry at the food-energy-water nexus. Co-sponsored with ENG/CBET, this workshop was held in October of 2015 and a report is forthcoming.

[3] http://sites.nationalacademies.org/BPA/BPA_087934
[4] www.nsf.gov/pubs/2015/nsf15115/nsf15115.jsp
[5] www.nsf.gov/pubs/2015/nsf15044/nsf15044.jsp
[6] www.nap.edu/catalog/15269/the-mathematical-sciences-in-2025
[7] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505044
[8] http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf
[9] http://science.energy.gov/~/media/np/nsac/pdf/docs/2016/NLDBD_Report_2015_Final_Nov18.pdf
[10] www.nsf.gov/mps/che/workshops/uarizona_few_nexus_workshop_report_final.pdf
[11] www.nsf.gov/mps/che/workshops/phosphorus_cycle_report_final.pdf

    - *Feeding the World in the 21st Century: Grand Challenges in the Nitrogen Cycle* covered chemical advances necessary for the efficient synthesis and use of nitrogen compounds for food production. Co-sponsored with ENG/CBET, this workshop was held in November of 2015 and the final report is forthcoming.
- The CCI program in CHE sponsored a CCI Diversity Forum, *Evidence-Based Practices for Broadening Participation in the Chemical Sciences* in May of 2015. The focus was drawing upon evidence-based practices from other programs and disciplines to develop strategic actions to broaden participation of the researchers in chemical sciences - racial and ethnic minorities, women, people with disabilities and veterans. The final report was submitted in 2015.[12]
- CHE supported a workshop on *Accelerating our Understanding of Supramolecular Chemistry in Aqueous Solutions* to identify multidisciplinary approaches for creating and understanding molecular assemblies in water. The workshop was held on May 31-June 4, 2015, and the final report is pending.
- DMR and CHE, together with the DOE Office of Basic Energy Sciences (BES) and the National Institute of Health (NIH), co-sponsored a workshop on *Ultrahigh Field NMR and MRI: Science at Crossroads* in November 2015. The workshop is a response to recommendations from the 2013 NRC report on *High Magnetic Field Science and its Applications in the United States: Current Status and Future Directions*.[13] The workshop's aim was to catalyze the development of a long-term ultrahigh field magnetic resonance science program in the U.S. The workshop report has been published.[14]
- DMR and the DOE/BES co-sponsored joint DOE/NSF Materials Genome Initiative (MGI) Principal Investigators' Meetings in January 2015 and January 2016. Bringing together investigators from NSF's DMREF program and the DOE's Predictive Theory and Modeling Program, the meetings are a venue for scientists to present and exchange information about their research, to foster new ideas and establish collaborations, and to discuss future research directions. They also help NSF and DOE in assessing the needs of this research community and in charting future directions.
- DMR, ENG's Division of Civil, Mechanical, and Manufacturing Innovation, and CISE's Division of Advanced Computational Infrastructure sponsored a workshop on Rise of Data in Materials Research in June 2015. The workshop provided an opportunity to discuss themes related to the rising importance of data in materials science with the aim of identifying high priority issues and work toward a concrete way forward to facilitate the emerging data revolution while fostering scientific excellence.
- DMR sponsored the *Condensed Matter Physics Broader Impacts Workshop* in January 2015. The workshop provided PI's with a venue to interact with each other and with program officers and to learn best practices for broader impacts. DMR also sponsored a workshop and a Webinar in 2015 for assistant professors seeking CAREER awards. PHY and DMR have been supporting Professional Skills Development Workshops for assistant professors organized by the American Physical Society for many years.
- DMR sponsored several workshops in 2015 that targeted a particular area of research or topic. Several workshops in 2016 will focus on ceramic science, polymer science, and soft condensed matter science.
- In response to the 2013 report of the project *Investing in the Next Generation through Innovative and Outstanding Strategies for Mathematics and Statistics* (INGenIOuS), DMS designed and implemented a new program in FY 2015, *Enriched Doctoral Training in the Mathematical Sciences* (EDT).[15] EDT, through research training, prepares Ph.D. students to recognize and find solutions to mathematical challenges arising in other fields and in areas outside today's academic setting. Following internal assessment of the first competitions of EDT, DMS convened a 2015 workshop at the Institute for Pure and Applied Mathematics that gathered input from representatives of business, industry, government, and academia on community needs, challenges, and opportunities in providing non-academic internship

[12] http://csp.umn.edu/wp-content/uploads/2015/07/Final-Report-CCI-Diversity-Forum.pdf
[13] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states
[14] https://sites.udel.edu/uhf-nmr-workshop/files/2015/08/UHF_workshop_report-176ncoq.pdf
[15] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505083

experiences for mathematical sciences Ph.D. students.

- DMS sponsored a 2015 community workshop on *Mathematical Sciences Challenges in Quantum Information*. The workshop report highlights the centrality and importance of mathematical tools in the field, assesses outstanding theoretical quantum information challenges, and identifies new areas.[16]
- In collaboration with NIH, DMS supported an Innovations Lab held at the Statistical and Applied Mathematical Sciences Institute in FY 2015 on Interdisciplinary Approaches to Biomedical Data Science Challenges. The activity fostered the formation of new interdisciplinary collaborations among mathematicians, statisticians, and biomedical science researchers. A Dear Colleague Letter, *Unsolicited Proposals for Quantitative Approaches to Biomedical Big Data (QuBBD)*[17] was issued to encourage proposals for collaborative research planning grants in this topic area, and ten planning grants were issued. A second Innovations Lab will be held in FY 2016.

Committees of Visitors (COV)

- In FY 2015, COVs reviewed AST, DMR, and PHY.[18]
- In FY 2016, COVs will review DMS and CHE.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in MPS Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	7,847	8,000	8,600
Other Professionals	3,232	3,100	3,300
Postdoctoral Associates	2,032	2,000	2,200
Graduate Students	9,022	8,700	9,400
Undergraduate Students	5,832	5,400	5,800
Total Number of People	**27,965**	**27,200**	**29,300**

[16] https://sites.google.com/site/mathqinfo2015/report.pdf
[17] www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf15093
[18] www.nsf.gov/mps/advisory/cov.jsp

DIVISION OF ASTRONOMICAL SCIENCES (AST) $262,610,000 +$15,880,000 / 6.4%

AST Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, AST	**$245.23**	**$246.73**	**$262.61**	**$15.88**	**6.4%**
Research	**67.65**	**62.32**	**73.16**	**10.84**	**17.4%**
CAREER	4.84	4.89	4.90	0.01	0.2%
Education	**5.49**	**6.50**	**6.00**	**-0.50**	**-7.7%**
Infrastructure	**172.09**	**177.91**	**183.45**	**5.54**	**3.1%**
Arecibo Observatory	4.01	4.10	4.20	0.10	2.4%
Atacama Large Millimeter Array (ALMA)	40.17	40.35	43.25	2.90	7.2%
Daniel K. Inouye Solar Telescope (DKIST)	7.00	11.00	16.00	5.00	45.5%
Gemini Observatory	20.61	19.88	20.42	0.54	2.7%
National Optical Astronomy Observatory (NOAO)	25.50	21.60	21.83	0.23	1.1%
National Radio Astronomy Observatory (NRAO)[1]	43.14	41.73	32.00	-9.73	-23.3%
National Solar Observatory (NSO)[2]	8.00	9.50	6.00	-3.50	-36.8%
Other Astronomical Facilities[1]	-	-	11.50	11.50	N/A
Mid-Scale Innovations Program (MSIP)	12.95	19.25	18.00	-1.25	-6.5%
Research Resources	10.71	10.50	10.25	-0.25	-2.4%

Totals may not add due to rounding.

[1] The decrease in NRAO support in FY 2017 is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now included under the "Other Astronomical Facilities" line in this table.

[2] The totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $14.0 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented in the DKIST line above.

The FY 2017 Budget Request for AST is $262.61 million, of which $247.73 million is discretionary funding and $14.88 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

AST is the federal steward for ground-based astronomy in the U.S., funding research with awards to individual investigators and small research groups and via cooperative agreements for the operation of large telescope facilities. These telescope facilities provide world-leading, one-of-a-kind observational capabilities on a competitive basis to thousands of astronomers each year. These facilities also enable scientific advances by making archived data products available to researchers. AST also supports the development of advanced technologies and instrumentation and manages the electromagnetic spectrum for scientific use by the entire NSF community.

AST supports research to understand the origins and characteristics of planets, stars and galaxies, as well as the structure that has evolved in the universe since its origin more than 13 billion years ago. The results of this research will lead to a better understanding of the cosmos, of the possibility of life existing on planets circling other stars, and of the nature of the mysterious dark matter and dark energy that comprise more than 95 percent of the mass-energy of the universe.

In general, 24 percent of the AST portfolio is available for new research grants and 76 percent is available for continuing grants. About 70 percent of AST's budget supports the forefront instrumentation and facilities needed for progress at the frontiers of observational astronomy, while almost 28 percent supports the research of individual investigators. Through the MREFC appropriation, AST also oversees the construction of LSST and DKIST.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*,[19] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences (AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*[20] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

In FY 2012 and FY 2013, AST began actively to engage in facility partnership discussions with other federal agencies and university-based groups. In FY 2014 and FY 2015, AST continued those talks, and NSF brought a general engineering contractor on-board for all its engineering and environmental reviews. In the first half of FY 2016, the contractor will deliver final feasibility reports for divestment alternatives, which will provide the results of baseline engineering and environmental surveys of a number of individual telescopes and observatories. Once NSF has identified viable options for divestment, it will embark on formal reviews in FY 2016 and FY 2017 to evaluate environmental impacts of these options, including partnership opportunities that could have impacts to the environment. Details for individual facilities are described in the Facilities chapter of this Budget Request.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>

- CAREER (+$10,000, to a total of $4.90 million): This continues AST's commitment to early-career investigators.
- Disciplinary and interdisciplinary research programs (+$10.15 million, to a total of $63.60 million): Support for fundamental research is a major focus. This increase will allow additional support to the Astronomy and Astrophysics (AAG) research program with a particular emphasis on cross-agency activities in
  - Optics and Photonics (-$500,000, to a total of $1.50 million): Decrease is due to low proposal pressure and higher priority needs in core research funding
  - CIF21 (+$1.45 million, to a total of $3.30 million): Funding supports LSST development and other CIF21 activities.
  - Networking and Information Technology Research and Development (NITRD) program (level at $7.67 million).
- Enhancing Access to the Radio Spectrum (EARS) (-$1.0 million to zero): AST is not funding this program in FY 2017 due to relatively low community demand.

[19] www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics
[20] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Education

- Partnerships in Astronomy and Astrophysics Research and Education (PAARE) (-$500,000, to a total of $1.50 million): Reduced proposal demand for PAARE in FY 2016 has resulted in a shift in the funding balance between PAARE and other workforce development and early-career programs.

Infrastructure

- ALMA (+$2.90 million, to a total of $43.25 million): Funding includes an increase of the annual contribution to the ALMA Development Fund agreed to by the international partners.
- Arecibo Observatory (+$100,000, to a total of $4.20 million): The increase covers added operating costs due to inflation.
- DKIST (+$5.0 million, to a total of $16.0 million): This increase supports the continued ramp-up of DKIST operations within NSO from $9.0 million to $11.50 million, plus the DKIST cultural mitigation award held steady at $2.0 million. Of the $16.0 million total, $2.50 million will be used to support the construction of the Remote Operations Building. See the Major Research Equipment and Facilities Construction chapter for more detail.
- Gemini Observatory (+$540,000, to a total of $20.42 million): This level accounts for slight increases in operations and maintenance and in the instrument development fund as agreed to by the international Gemini Board.
- NOAO (+$230,000, to a total of $21.83 million): This change includes an increase in the NOAO base (+$530,000 to a total of $18.03 million) and a decrease for special projects in partnership with NASA and DOE (-$300,000, to a total of $3.80 million).
- NRAO (-$9.73 million, to a total of $32.0 million): This decrease is due to the removal of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the NRAO base budget in FY 2017. Funding for GBO and VLBA is captured in the Other Astronomical Facilities line as discussed below.
- NSO (-$3.50 million, to a total of $6.0 million): Of the total change, most (-$2.50 million to zero) is due to the end of a one-time activity to make NSO Space Weather infrastructure more robust, and the rest (-$1.0 million to a total of $6.0 million) is due to a decrease in NSO base support as emphasis shifts to DKIST operations.
- Other Astronomical Facilities (+$11.50 million, to a total of $11.50 million): This line captures operational support for GBO and VLBA, which were moved from the NRAO base budget as noted in the NRAO bullet above.
- Mid-Scale Innovations Program (MSIP) (-$1.25 million, to a total of $18.0 million): This change is due to re-balancing MSIP with core individual investigator programs for which funding also decreases.
- Research Resources (-$250,000, to a total of $10.25 million): This decrease, to a total of $250,000, constitutes the final increment of a five-year planning award for the Giant Segmented Mirror Telescope that is scheduled to end in FY 2017. Funding for other activities on this line, the Advanced Technologies and Innovation program and Dark Energy Survey Data Management, remain constant at about $8.0 million and $2.0 million, respectively.

DIVISION OF CHEMISTRY (CHE) $262,160,000

+$15,850,000 / 6.4%

CHE Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, CHE	**$246.29**	**$246.31**	**$262.16**	**$15.85**	**6.4%**
Research	**232.65**	**235.15**	**249.88**	**14.73**	**6.3%**
CAREER	28.10	23.91	24.18	0.27	1.1%
Centers Funding (total)	34.91	28.35	29.75	1.40	4.9%
Centers for Chemical Innovation	34.66	28.10	29.50	1.40	5.0%
Nanoscale Science & Engineering Centers	0.25	0.25	0.25	-	-
Education	**6.34**	**5.85**	**5.05**	**-0.80**	**-13.7%**
Infrastructure	**7.30**	**5.31**	**7.23**	**1.92**	**36.2%**
National High Magnetic Field Laboratory (NHMFL)[1]	1.88	-	1.92	1.92	N/A
National Nanotechnology Coordinated Infrastructure (NNCI)	0.20	0.30	0.30	-	-
Research Resources	5.22	5.01	5.01	-	-

Totals may not add due to rounding.

[1] Forward funding of $1.88 million in FY 2015 reduced to zero the amount required in FY 2016.

The FY 2017 Budget Request for CHE is $262.16 million, of which $247.31 million is discretionary funding and $14.85 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

CHE supports a large and vibrant research community engaged in fundamental molecular and nano-science research linked to key national priorities. CHE will enable research in sustainability and clean energy, providing new molecules and tools that are essential to our economy and well-being. Through the development of new methodologies in chemical synthesis and catalysis, CHE is a natural contributor to advanced manufacturing technology. CHE strongly supports research at the interfaces with biology and materials science, within both experimental and theoretical/computational frameworks. CHE-supported research will also enable new solutions to problems at the nexus of food, energy and water systems. CHE's programs invite research in catalysis for energy capture and storage as well as for the formation of new chemical bonds, appreciation of, and insight into, the chemistry of life processes, new nano-structured materials that will revolutionize electronics and photonics, and better awareness of how nano-size aerosols and particles impact our environment. In addition, CHE supports curiosity-driven research that leads to increased understanding of molecules and their chemical transformation, as well as the development of new instrumentation to study and detect molecules.

In general, 63 percent of the CHE portfolio is available for new research grants, and the remaining 37 percent is used primarily to fund continuing grants made in the previous years. Almost 86 percent of CHE's budget is used to support individuals and small groups of researchers, while over 14 percent of the budget supports centers and facilities.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$270,000, to a total of $24.18 million): CHE continues its commitment to young investigators; this investment level scales with the divisional budget.
- Disciplinary and Interdisciplinary Research (+$12.42 million, to a total of $191.32 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - Advanced Manufacturing (-$5.20 million, to a total of $14.54 million) continues to be important for CHE, with projects supported both through unsolicited individual investigator awards and through the Centers for Chemical Innovation program. Reductions in funding are due to competing priorities within the individual investigator portfolio.
  - BioMaPS (no change at $3.24 million): Research at the chemistry-biology interface is an important area of the chemical sciences. Funding will strengthen research programs in advanced spectroscopic and imaging techniques for biomolecules and biosystems, metal speciation, coordination and function, chemical studies of enzyme and ribozyme catalysis, and other studies at the chemistry-biology frontier.
  - CIF21 (+$800,000, to a total of $2.65 million): CHE will accelerate research by investing in new functional capabilities in computational methods, algorithms, tools and data core methods, and technologies.
  - Clean Energy (+$21.31 million, to a total of $90.0 million): Additional research in the CHE clean energy portfolio includes hydrogen, fuel cells, biomass, solar energy, hydrocarbon conversion, the capture and use of CO_2, and energy storage.
  - INFEWS (+$1.0 million, to a total $3.0 million): Increased support of research will occur in this NSF-wide program via joint solicitations, Dear Colleague Letters, and unsolicited proposals to divisional programs.
  - UtB (-$1.08 million, to a total $3.80 million): CHE continues support for this cross-NSF activity. The reduction brings the commitment in line with the FY 2015 level and reflects competing priorities within the individual investigator portfolio.
- Centers for Chemical Innovation (+$1.40 million, to a total of $29.50 million): Funding is expected to support nine Phase II centers and up to three Phase I awards selected in a new competition planned for FY 2017. An evaluation of this program is anticipated to begin in FY 2017.

Education

- Research Experiences for Undergraduates (REU) (level at $5.05 million): CHE maintains a commitment to REU Sites and REU Supplements activities.

Infrastructure

- NHMFL (+$1.92 million, to a total of $1.92 million): CHE funding supports the maintenance and operation of the 21-Tesla magnet at the Ion Cyclotron Resonance (ICR) facility. Forward funding of $1.88 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request level is consistent with the commitment in the current cooperative agreement.
- Research Resources (no change at $5.01 million): This includes support for the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCARS) at Argonne National Laboratory and for highly meritorious Major Research Instrumentation (MRI) program proposals.

DIVISION OF MATERIALS RESEARCH (DMR) $329,710,000

+$19,680,000 / 6.3%

DMR Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, DMR[1]	**$337.62**	**$310.03**	**$329.71**	**$19.68**	**6.3%**
Research	**273.69**	**250.65**	**261.05**	**10.40**	**4.1%**
CAREER	23.28	21.53	21.78	0.25	1.2%
Centers Funding (total)	86.55	60.34	60.45	0.11	0.2%
Materials Research Science & Engineering Centers[1]	79.66	56.00	56.00	-	-
Nanoscale Science & Engineering Centers	0.25	0.25	0.25	-	-
STC1: Center for Layered Polymeric Materials	2.66	-	-	-	N/A
STC2: Center for Integrated Quantum Materials	3.98	4.09	4.20	0.11	2.7%
Education	**11.14**	**5.60**	**5.60**	**-**	**-**
Infrastructure	**52.79**	**53.78**	**63.06**	**9.28**	**17.3%**
Cornell High Energy Synchrotron Source (CHESS)[2]	11.97	8.03	10.00	1.97	24.5%
National High Magnetic Field Laboratory (NHMFL)[3]	34.04	22.78	33.86	11.08	48.6%
National Nanotechnology Coordinated Infrastructure (NNCI)	2.68	2.58	2.58	-	-
Mid-scale Research Infrastructure	-	16.29	12.50	-3.79	-23.3%
Research Resources	1.33	1.33	1.33	-	-
Center for High Resolution Neutron Scattering (CHRNS)	2.77	2.77	2.79	0.02	0.7%

Totals may not add due to rounding.

[1] Due to delayed awards processing, funding for FY 2015 includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

[2] Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[3] Forward funding of $10.0 million in FY 2015 reduced the amount required in FY 2016.

The FY 2017 Budget Request for DMR is $329.71 million, of which $311.03 million is discretionary funding and $18.68 million is new mandatory funding. The mandatory funding is within the Research line in the above table**.**

DMR research looks at advancing materials discovery, design, synthesis, and characterization. Programs focus on condensed matter physics, solid-state and materials chemistry, and the science of materials that are ceramic, metallic, polymeric, nano-structured, biological, electronic, photonic, and multifunctional. DMR awards enable understanding of the electronic, atomic, and molecular mechanisms and processes that govern macroscale to nanoscale properties, manipulation and control of these properties, discovery of emerging phenomena, and creation of novel design, synthesis, and processing strategies that lead to new materials with unique characteristics.

These discoveries transcend traditional scientific and engineering disciplines. They enable new technologies that meet societal needs. DMR-supported research is essential for the development of future technologies and industries. A critical enabler to these scientific advances is the investment in the materials workforce, cyberinfrastructure, materials centers, and next generation instruments and facilities, including support for mid-scale user facilities called Materials Innovation Platforms (MIP). A MIP, in addition to providing access to new instrumentation, conducts research on a materials challenge by integrating synthesis, characterization, and materials theory or modeling. It aligns with goals of Advanced Manufacturing as well as the national Materials Genome Initiative. Finally, conveying the exciting science and the societal benefit enabled by materials research to students and to the general public remains an important aspect of the division's mission.

In general, about 33 percent of the DMR portfolio is available for new research grants and 67 percent goes to continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$250,000, to a total of $21.78 million): DMR places high priority on these grants in order to develop a pipeline of new faculty who will help form the community of the future.
- Disciplinary and Interdisciplinary Research (+$9.24 million, to a total of $172.97 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - CEMMSS: DMR participates in the CEMMSS and Advanced Manufacturing initiatives (both level at $23.67 million) through DMREF (+$1.65 million, to $13.90 million), MIP (described below under Research Infrastructure), the Scalable Nanomanufacturing program, and through MRSECs and other core program investments. DMREF and MIP (described below under Research Infrastructure) are major efforts to accelerate the discovery and deployment of new materials with a specific and desired function or property through synergistic integration of theory and computation, experiments, and systematic use of materials data. These latter activities are well aligned with the Materials Genome Initiative.
  - CIF21 (level at $2.65 million): Support continues for research in the cyberinfrastructure needed for CEMMSS/DMREF and MIP, by investing in new functional capabilities in computational methods, algorithms, tools and data core methods, and technologies.
  - Clean Energy (+$13.24 million, to a total of $83.36 million): Funding supports fundamental materials research that enables advances in hydrogen production, fuel cells, biomass, solar energy, hydrocarbon conversion, the capture and use of CO_2, and energy storage
  - SEES (level at $3.0 million): Support for SEES comes through the Sustainable Chemistry, Engineering and Materials (SusChEM) program, with a focus on fundamental materials research. As SEES sunsets as planned in FY 2017, DMR will begin investments in sustainable materials through INFEWS at $3.0 million.
  - UtB (-$1.08 million, to a total of $3.80 million): DMR increased support in this agency-wide focus in FY 2016. The FY 2017 Request returns to the FY 2015 level. Some of the DMR investment in UtB are connected to activities supported by BioMaPS.
- MRSECs (level at $56.0 million): MRSECs support interdisciplinary materials research and education of the highest quality while addressing fundamental problems in materials science of a scope and complexity requiring the scale and synergy provided by a center.
- STCs (+$109,000, to a total of $4.20 million): The materials community has been very active in seeking STC funding. A ramp up in support for the Center on Integrated Quantum Materials from the 2013 cohort is consistent with the current cooperative agreement. Funding for the Center for Layered Polymeric Systems from the 2005 cohort ended as planned in FY 2015 after ten successful years.

Education[21]

- REU (level at $5.17 million): DMR's education portfolio maintains commitments to this program that supports active participation in scientific research by undergraduate students in meaningful ways.

Infrastructure

- CHESS (+$1.97 million, to a total of $10.0 million): Funding will support this national user facility of high-energy X-rays, which serves researchers in fields of biology, engineering, and materials. Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement. (ENG and BIO contributions remain level at $5.0 million each.)
- NHMFL (+$11.08 million, to a total of $33.86 million): This unique facility, using extremely high magnetic fields, enables transformative research in fields ranging from biology, chemistry, to materials and condensed matter physics. Forward funding of $10.0 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the commitment in the current cooperative agreement.
- Mid-scale Research Infrastructure (-$3.79 million, to a total of $12.50 million): Launch of the Materials Innovation Platforms (MIP), originally planned for FY 2015, was delayed to FY 2016. The two MIPs in the inaugural class embrace the goals set forth by the Materials Genome Initiative and include closed-loop efforts in materials synthesis, characterization, theory, modeling and/or simulation. They are designed to help enabling Advanced Manufacturing capability in the U.S. through support of bulk crystal growth, as well as fabrication of novel materials. The decrease in the FY 2017 Request reflects a planned ramp down of equipment purchases in the second year. MIP competitions are planned triennially. The next competition is currently scheduled for FY 2018.
- Research Resources (level at $1.33 million): This funding supports the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCARS) and instrumentation for materials research.
- Center for High Resolution Neutron Scattering (CHRNS) (level at $2.77 million): Funding is held level for this effort.

[21] FY 2015 Actual funding under Education includes education activities, such as REU awards, via the MRSECs. FY 2016 Estimate and FY 2017 Request funding captures these activities on the MRSEC line under Research.

DIVISION OF MATHEMATICAL SCIENCES (DMS) $249,170,000

+$15,120,000 / 6.5%

DMS Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, DMS	**$235.43**	**$234.05**	**$249.17**	**$15.12**	**6.5%**
Research	**223.27**	**226.56**	**241.68**	**15.12**	**6.7%**
CAREER	13.05	9.65	9.85	0.20	2.1%
Centers Funding (total)	0.20	0.20	0.20	-	-
Centers for Analysis & Synthesis	0.20	0.20	0.20	-	-
Education	**12.16**	**7.49**	**7.49**	**-**	**-**

Totals may not add due to rounding.

The FY 2017 Budget Request for PHY is $249.17 million, of which $235.05 million is discretionary funding and $14.12 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

DMS plays a critical role in providing more than 60 percent of all U.S. federal support of basic research at the frontiers of discovery in the mathematical sciences.

The influence of mathematical sciences on daily life is fundamental and pervasive; for example, every secure commercial transaction on the internet is an application of research in number theory and algebraic geometry, and similarly many of the modern smart materials used in advanced manufacturing are the result of mathematical analysis and simulation. Modern communication, transportation, medicine, manufacturing, security, and finance all depend on developments in the mathematical sciences.

DMS investments catalyze research at the frontiers of fundamental, applied, and computational mathematics and statistics and enable discovery and innovation in other fields of science and engineering linked to key national priorities. In turn, advances in science and engineering inspire development of ever more sophisticated mathematical and statistical methodologies, theories, and tools. DMS investments underpin these developments as well as the training of future researchers in the mathematical sciences.

In addition to supporting a vibrant research community through core research programs in mathematics and statistics, DMS supports a range of other investments that advance research, increase the impact of the mathematical sciences, respond to national needs, and expand the U.S. talent base engaged in mathematical and statistical research. These include mathematical sciences research institutes, multi-agency programs such as a joint activity in biosciences with the National Institute of General Medical Sciences, as well as initiatives in data science. A newer DMS activity, the Mathematical Sciences Innovation Incubator, supports the involvement of the mathematical sciences community in collaborative research projects that address national priorities, including the National Strategic Computing Initiative (SCI), climate science research, and clean energy research. The DMS workforce program offers funding opportunities that support efforts to increase the number of well-prepared students who pursue careers in the mathematical sciences in all sectors. These investments in mathematical sciences discovery, connections, and community are essential components of the innovation engine that drives the nation’s economy in the 21st century.

In general, 52 percent of the DMS portfolio is available for new research grants and 48 percent goes to continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$200,000, to a total of $9.85 million): Support for early-career researchers is a division priority. This increase allows DMS to support larger CAREER awards.
- Disciplinary and Interdisciplinary Research (+$14.30 million, to a total of $226.51 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - BioMaPS (level at $3.26 million): DMS invests in this area in a comprehensive approach to acquire insight into and inspiration from the living world.
  - CEMMSS (+$3.50 million, to a total of $5.60 million): Funding will accelerate fundamental discoveries in materials science and Advanced Manufacturing by investing in new capabilities for mathematical modeling, computational simulation, numerical algorithms, and data analysis and management.
  - CIF21 (+$1.60 million, to a total of $4.90 million): Increased investment will promote the creation and development of the next generation of mathematical and statistical theories and tools that address the challenges presented to the scientific and engineering communities by the ever-expanding role of computational modeling and simulation on the one hand, and the explosion in production of digital and observational data on the other.
  - INFEWS (level at $400,000) and Risk and Resilience (level at $500,000): Research on fundamental scientific issues, such as understanding the dynamical processes that produce extreme events, will advance knowledge and help to create tools for increased resilience of societal infrastructure to natural and anthropogenic hazards.
  - Optics and Photonics (+$2.0 million, to a total of $3.50 million): Investment here reflects increased community interest. DMS leads MPS participation in this multidisciplinary, NSF-wide activity, which is key to enabling technologies in a multitude of application. DMS coordinates the crosscutting Optics and Photonics Working Group that manages co-review of multidisciplinary proposals in collaboration with other participating directorates. The activity will be highlighted through community workshops and the development of a program solicitation.
  - SaTC (level at $2.0 million): Funding reflects continued national need for fundamental cybersecurity research, which investigates questions surrounding securing information networks against hostile intrusion and ensuring individual privacy in anonymized data sets.
  - UtB (+$425,000, to a total of $5.30 million): DMS support increases scientific understanding of the full complexity of the brain, in action and in context, through targeted, cross-disciplinary investments.
  - Mathematical Sciences Research Institutes (-$2.0 million, to a total of $25.20 million): Seven DMS-supported institutes will continue to catalyze frontier research through an array of scientific programs.

Education

- REU (level at $3.39 million): Funding commitments continue to these research experiences for undergraduate students.
- Mathematical Sciences Postdoctoral Research Fellowships (level at $4.10 million). Investments continue in a number of education and diversity activities through the program.

DIVISION OF PHYSICS (PHY) $295,260,000
+$18,230,000 / 6.6%

PHY Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, PHY	**$276.10**	**$277.03**	**$295.26**	**$18.23**	**6.6%**
Research	**169.33**	**174.51**	**189.69**	**15.18**	**8.7%**
CAREER	8.83	7.55	7.74	0.19	2.5%
Education	**5.60**	**5.16**	**5.16**	**-**	**-**
Infrastructure	**101.17**	**97.36**	**100.41**	**3.05**	**3.1%**
IceCube	3.45	3.45	3.50	0.05	1.4%
Large Hadron Collider (LHC)	18.00	18.00	20.50	2.50	13.9%
Laser Interferometer Grav. Wave Obs. (LIGO)	33.00	39.43	39.43	-	-
Nat'l Superconoducting Cyclotron Lab. (NSCL)	23.00	24.00	24.50	0.50	2.1%
Midscale Research Infrastructure	23.72	12.48	12.48	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for PHY is $295.26 million, of which $278.53 million is discretionary funding and $16.73 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

PHY supports fundamental research addressing frontier areas of physics that lead to the understanding of the make-up of the Universe, from the formation of stars and galaxies to the principles of life processes on Earth. This research covers a range of physics subfields: atomic, molecular, optical and plasma physics, elementary particle physics, gravitational physics, nuclear physics, particle and nuclear astrophysics, physics of living systems, physics at the information frontier, and theoretical physics. PHY is the primary supporter of all research in the U.S. in gravitational physics and the leading supporter of fundamental research in atomic, molecular, and optical physics in the United States. PHY is a major partner with DOE in support of elementary particle physics, nuclear physics, and plasma physics. PHY also has the only U.S. program designed for the support of physics research in living systems. The development of the most advanced cutting-edge computational resources, innovative technology, and new instrumentation is a key part of physics research, and tools developed by the physics community continuously have major impact in other scientific and engineering fields.

In general, about 21 percent of the PHY portfolio is available for new research grants. The remaining 79 percent is used primarily to fund continuing grants made in previous years (47 percent) and to support operations and maintenance for four facilities that are a key part of the division portfolio (32 percent).

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate level.

<u>Research</u>

- CAREER (+$190,000, to a total of $7.74 million): This modest increase continues PHY’s commitment to early-career researchers.
- Disciplinary and Interdisciplinary Research (+$14.28 million, to a total of $176.82 million): Support

for fundamental research is a major focus. Funding will allow added emphasis on NSF-wide investments such as these:

- BioMaPS (flat at $3.26 million): This initiative provides for programs that support research at the interface between the mathematical and physical sciences and the life sciences.
- CEMMSS (-$1.0 million, to a total of $3.33 million): Decreased support reflects other division priorities.
- CIF21 (+$800,000, to a total of $2.65 million): Increased support is due to continued strong community interest in this area.
- UtB (+$930,000 to $5.80 million): This provides support for physics-based research that enables scientific understanding of the full complexity of the brain, in action and in context.

Education

- REU (level at $5.06 million): Funding is level in this research experiences program for undergraduates.
- Additionally, $650,000 will support efforts to broaden participation by groups traditionally underrepresented in the physical sciences. Support will be made through internal co-funding.

Infrastructure

- IceCube (+$50,000, to a total of $3.50 million): Funding reflects a slight increase in operations per the cooperative agreement.
- LHC (+$2.50 million, to a total of $20.50 million): This supports operations of the ATLAS and CMS detectors at LHC. The additional funding during enables research and development and planning that could possibly lead to a major construction upgrade beginning in FY 2020.
- LIGO (level at $39.43 million): This supports operations of LIGO and commissioning of its upgraded interferometer following completion of the Advanced LIGO construction project in FY 2014.
- NSCL (+$500,000, to a total of $24.50 million): This supports operations of the NSCL at Michigan State University. Added funding enables support for full operations of NSCL, including the recently commissioned reacceleration facility (ReA3). Recent external site reviews provided updated guidance on management and operations costs for the laboratory.
- Midscale Research Infrastructure (level at $12.48 million): Support will continue for midscale level instrumentation support. (The large number in FY 2015 is due to forward funding from FY 2014 of existing commitments.)

OFFICE OF MULTIDISCIPLINARY ACTIVITIES (OMA) $37,540,000
+$2,540,000 / 7.3%

OMA Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, OMA	**$35.65**	**$35.00**	**$37.54**	**$2.54**	**7.3%**
Research	**29.78**	**27.39**	**30.00**	**2.61**	**9.5%**
CAREER	0.96	-	-	-	N/A
Education	**5.87**	**7.61**	**7.54**	**-0.07**	**-0.9%**

Totals may not add due to rounding.

The FY 2017 Budget Request for OMA is $37.54 million, of which $35.41 million is discretionary funding and $2.13 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

OMA enables and facilitates MPS support of novel, challenging, or complex projects of varying scale, in both research and education, which are not readily accommodated by traditional organizational structures and procedures. This is done primarily in partnership with MPS disciplinary divisions and is especially directed at activities by multi-investigator, multidisciplinary teams, as well as cross-NSF and interagency activities.

In FY 2017, OMA will focus on multidisciplinary research (chiefly through award co-funding) that emphasizes the mathematical and physical scientific foundations of sustainability. This includes issues affecting the nexus of food, energy, and water; fundamental science critical to the discovery, understanding, and development of new materials; fundamental scientific advancements that are enabled by investments in midscale infrastructure, basic research at the interface between the mathematical and physical sciences and the life sciences that will lead to new insights into the molecular basis of life processes and to a better understanding of the healthy human brain and that of model animal species; multidisciplinary explorations in optics and photonics, including light-matter interaction at the nanoscale that encompass materials, devices, and systems; the understanding, control, and manipulation of the behavior of quantum matter and the limitations of quantum information processing, including the roles of spintronics and topological insulators; and team efforts aimed at the development of next-generation instrumentation to enable fundamental advances across a wide spectrum of disciplines. OMA also will provide leadership and support for I-Corps™ activities within MPS.

In general, about 54 percent of the OMA portfolio is available for new research grants and 46 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Disciplinary and Interdisciplinary Research (+$5.57 million, to a total of $20.80 million): In FY 2017, OMA will focus on multidisciplinary research that addresses the key MPS and NSF-wide investments such as Optics and Photonics, INFEWS, CIF21, CEMMSS, BioMaPS, Clean Energy, UtB, and I-Corps™.

- I-Corps™ (level at $1.70 million): Investments are directed to an assessment of the commercial viability of the scientific discoveries in MPS disciplines through the individual investigator award program.
- INSPIRE (-$3.0 million to zero): Through a planned phase-out the OMA investment decreases to zero.

Education

- Career Life Balance (level at $400,000): OMA will coordinate these award supplements for the directorate.
- NRT: Funding for NRT increases (+$290,000, to a total of $4.54 million) while final commitments within the Integrative Graduate Education and Research program (-$220,000 to zero) were completed in FY 2016. OMA will contribute the entire amount of NRT funding for MPS.

Facilities

- Portfolio analysis (no change, for a total up to $7.0 million): OMA will support responsible decision making regarding implementation of portfolio analysis recommendations. This investment will support studies of possible environmental issues, stewardship transition costs, or partnership program start-up costs.

DIRECTORATE FOR SOCIAL, BEHAVIORAL, AND ECONOMIC SCIENCES (SBE) — $288,770,000 +$16,570,000 / 6.1%

SBE Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Social and Economic Sciences (SES)	$98.36	$98.18	$105.42	$7.24	7.4%
Behavioral and Cognitive Sciences (BCS)	97.03	95.06	102.08	7.02	7.4%
National Center for Science and Engineering Statistics (NCSES)	50.94	50.76	51.76	1.00	2.0%
SBE Office of Multidisciplinary Activities (SMA)	29.86	28.20	29.51	1.31	4.6%
Total, SBE	**$276.19**	**$272.20**	**$288.77**	**$16.57**	**6.1%**

Totals may not add due to rounding.

The FY 2017 Budget Request for SBE is $288.77 million, of which $272.41 million is discretionary funding and $16.36 million is new mandatory funding. The major focus of the mandatory funding is support for core activities, with special emphasis on early career investigators. SBE seeks to inspire and invest in the next generation of scientists who will be able to capitalize on the availability of massive amounts of different types of data – for example, data that combine surveys, administrative records, brain imaging, and output from behavioral and geographic sensors – to advance knowledge about human behavior. As young scientists embark on their careers, they bring novel and far reaching ideas into play that can transform the future. They will seed the next harvest of discoveries in the social, behavioral, and economic sciences that support the Nation’s economy, security, and global leadership. Examples of SBE activities in these areas include:

- Improve the overall success rate of high-quality research proposals, especially those submitted by early career investigators, by strengthening funding for core disciplinary programs;
- Support for pilot workshops and institutes on proposal development, robust and reliable research designs, data-sharing approaches, and analytic techniques to equip early career investigators with the skills to conduct and garner funding for research in the era of “Big Data” and new approaches to human neuroscience research; and
- Support for research enhancing the robustness and reliability of science.

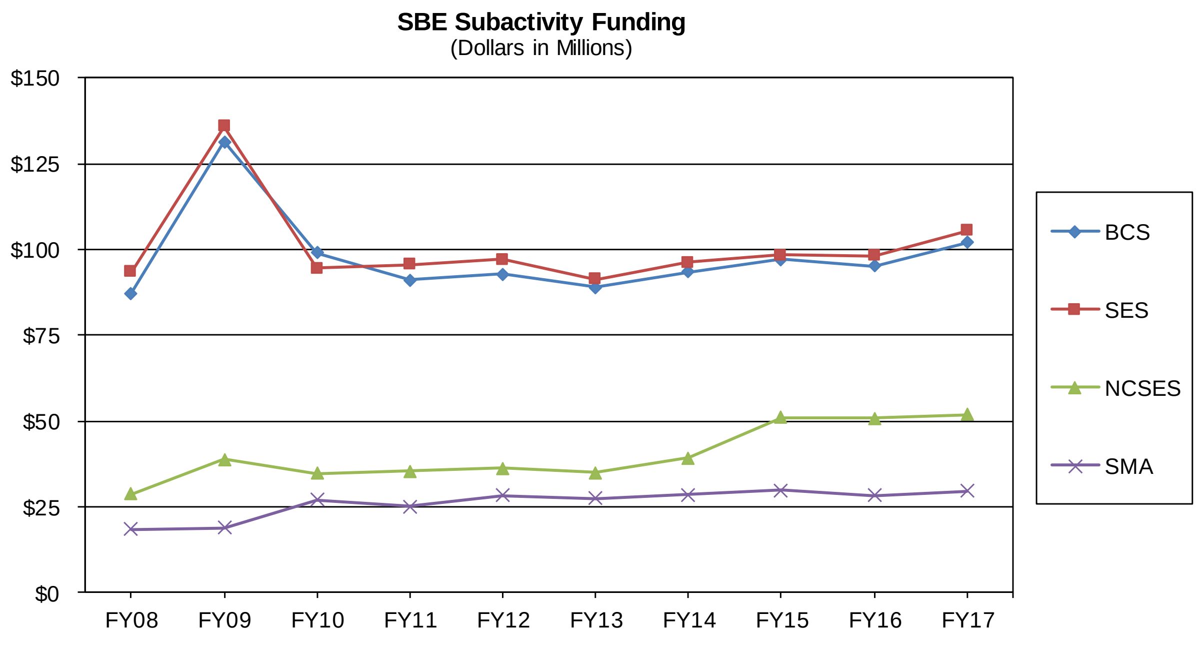
About SBE

SBE’s mission is to promote the understanding of people and their lives by supporting research that reveals basic facets of human behavior and social institutions; encouraging research that addresses important societal questions and problems; working with other scientific disciplines to ensure that basic research and solutions to problems build upon the best disciplinary and multidisciplinary science; and providing mission-critical statistical information about science and engineering (S&E) in the U.S. and the world through the National Center for Science and Engineering Statistics (NCSES). SBE supports research across a diverse range of sciences that includes anthropology, archaeology, economics, geography, linguistics, neuroscience, political science, psychology, sociology, and statistics. SBE combines these sciences in interdisciplinary activities linking these fields to each other and to other science and engineering fields. SBE is a significant partner in cross-directorate programs that connect the social, behavioral, and economic sciences to priority investments across the agency. SBE provides approximately 66 percent of the federal funding for basic research at academic institutions in the social, behavioral, and economic sciences.

SBE’s FY 2017 Budget Request is informed by four key priorities: (1) enhancing research investments that advance fundamental knowledge in the social, behavioral, and economic sciences; (2) supporting the directorate's ongoing interdisciplinary research and training activities; (3) participating in cross-directorate and NSF-wide priority activities in which a comprehensive understanding of human behavior – at the individual, group, and/or organizational levels, across different scales of space and time – is central; and (4) supporting the work of NCSES as the Nation's leading provider of statistical data on the S&E enterprise. NCSES collects and analyzes data on research and development, the S&E workforce, the condition and progress of science, technology, engineering, and mathematics (STEM) education, and U.S. competitiveness in science, engineering, technology, and research and development.

SBE's Budget Request for FY 2017 includes continued investments that integrate the social, behavioral, and economic sciences into multi-directorate and multi-disciplinary activities that address issues of major scientific, national, and societal importance. These priority investments include Understanding the Brain (UtB); Cyberinfrastructure for 21st Century Science, Engineering, and Education (CIF21); the Comprehensive National Cybersecurity Initiative (CNCI) via the Secure And Trustworthy Cyberspace (SaTC) investment; Risk and Resilience via the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program; and Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS). SBE will also invest in the NSF-wide effort to increase participation of underrepresented groups in STEM fields, via the Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) program.

The FY 2017 Budget Request for SBE also increases funding in core disciplinary programs in order to bolster the success rate of highly meritorious proposals received by SBE that would otherwise be declined; supports research focused on robust and reliable science; and broadens participation from underrepresented groups and geographical regions.



FY 2009 reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- SES's FY 2017 Request reflects its strong contribution to the unifying themes in the FY 2017 NSF Budget Request by supporting several NSF-wide investments that cross multiple scientific disciplines. This includes support for CIF21 to address issues related to data infrastructure for the social, behavioral, and economic sciences; funding for CRISP as part of the Risk and Resilience investment, which focuses on the key social and behavioral research questions that are relevant for understanding risk and resilience of both designed and natural systems and of individuals interacting within and affected by these systems; and continued investments in SaTC by supporting social, behavioral, and economic sciences research that seeks to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity. SES contributes to the NSF-wide INFEWS program as well as the Smart and Connected Communities activity, both initiated in FY 2016. SES will maintain its commitment to existing programs and continue support for surveys that provide unique insights into U.S. social, economic, and political life while providing funding for new research that has the potential to transform the social and economic sciences and inform policy development. SES will increase funding for the Faculty Early Career Development (CAREER) program. SES will continue efforts to build the scientific foundation and research evidence base needed for future programmatic efforts in broadening the participation of women, early career investigators, underrepresented minorities, and people with disabilities in S&E via investments in the Science of Broadening Participation (SBP) and the NSF INCLUDES programs. In FY 2017, SES will maintain investment in the National Nanotechnology Coordinated Infrastructure (NNCI), the successor to the National Nanotechnology Infrastructure Network (NNIN).

- As a critical aspect of the leadership provided by BCS in basic human neuroscience research, in FY 2017, BCS will continue to be a lead in the UtB activity while maintaining its robust investment in this research area. BCS will also be a partner in two interdisciplinary activities established in FY 2016: the NSF-wide INFEWS activity and the emerging multi-directorate Smart and Connected Communities research area. BCS will invest in CAREER, emphasizing the importance of developing scientific intellectual capital for the U.S.; in CRISP as part of the Risk and Resilience portfolio; in CIF21; and continue its investment in the science of learning. BCS will expand support for behavioral, cognitive, anthropological, and geographic research that informs and deepens understanding of basic psychological and behavioral scientific questions that can inform critical issues facing the Nation, such as terrorism, pandemics, sustainability, and forensic science. In its ongoing programs, BCS will operate in an interdisciplinary context, providing support for research on the complex ways people think, adapt, and interact with social, natural, and built environments. BCS support for SaTC will enable research about cognitive and behavioral aspects of threats to cybersecurity. BCS will continue efforts to broaden the participation of women, underrepresented minorities, young investigators, and people with disabilities in science and engineering via its existing disciplinary programs, SBP, and NSF INCLUDES. BCS will continue to fund basic research that advances understanding of cognition and behavior through various research mechanisms.

- In FY 2017, NCSES will maintain its core programmatic data collection and publication activities. NCSES will invest in activities that support: (1) development of enhanced data access tools, techniques, and visualizations including integration of the Scientists and Engineers Statistical Data System (SESTAT) and WebCASPAR, into a combined database and interface to provide easy access to a large body of statistical data resources for S&E at U.S. academic institutions; (2) new data collection techniques building on administrative data and other "big data" sources; and (3) questionnaire redesign and survey improvements to support improved data on measures of innovation and educational and career pathways for scientists and engineers. Additionally, NCSES will continue to pursue significant and strategic targeted improvements – initiated in FY 2015 – in its statistical and analytic programs. NCSES will continue to develop and test new measures from the Survey of

Doctorate Recipients (SDR) that address data gaps related to understanding the relationship between federal support for graduate education and student outcomes such as employment. NCSES will work to close a growing gap in its national estimates for research and development by fielding a survey of research activities in nonprofit organizations. Responding to recommendations in the Committee on National Statistics report, *Capturing Change in Science, Technology and Innovation*,[1] NCSES will develop a conceptual framework for and test potential indicators of innovation. Throughout, NCSES will work to increase international comparability, particularly on the S&E workforce and innovation metrics.

- SMA provides a focal point for programmatic activities that cut across NSF's and SBE's disciplinary boundaries. SMA will maintain investment in UtB and CIF21. SMA will continue to play an important role in the expansion of interdisciplinary training and broadening participation with continued support and management of the SBE Postdoctoral Research Fellowships (SPRF) program. Support for enhancing the research experience for students will continue via sustained investments in the Research Experiences for Undergraduates (REU) Sites and Supplements programs. SMA will continue support of interdisciplinary activities associated with the Science of Science and Innovation Policy (SciSIP) program, as well as efforts to make NSF-funded research available to the public through the Public Access Initiative. SMA will continue to participate in the NSF Innovation Corps (I-Corps™), and SaTC programs.

Major Investments

SBE Major Investments
(Dollars in Millions)

				Change Over FY 2016 Estimate	
Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Amount	Percent
ADVANCE	$1.00	$1.00	$1.00	-	-
CAREER	8.52	7.27	7.37	0.10	1.4%
CIF21	6.57	6.82	6.82	-	-
NSF I-Corps™	0.50	0.50	0.50	-	-
NSF INCLUDES	-	0.50	0.50	-	-
INFEWS	-	4.50	4.50	-	-
NRT[1]	2.52	2.59	0.64	-1.95	-75.3%
Public Access	0.82	1.75	1.75	-	-
Risk and Resilience	1.84	4.90	4.90	-	-
SaTC	4.00	4.00	4.00	-	-
SciSIP	11.17	11.05	11.05	-	-
SEES	3.00	-	-	-	N/A
Smart and Connected Communities	-	1.50	1.50	-	-
Understanding the Brain	22.97	25.00	25.00	-	-
BRAIN Initiative	*4.53*	*7.17*	*7.17*	-	-

Major investments may have funding overlap and thus should not be summed.

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $420,000 in FY 2015, $2.09 million in FY 2016, and $0 in FY 2017.

[1] www.nap.edu/catalog/18606/capturing-change-in-science-technology-and-innovation-improving-indicators-to

- ADVANCE ($1.0 million): SBE will continue to participate in the NSF-wide program ADVANCE as part of its ongoing commitment to broaden participation to build strategies and models to increase the participation, retention, and advancement of women in all STEM academic careers.

- CAREER: SBE supports CAREER (+$100,000, to a total of $7.37 million) with awards to early-stage investigators in the social and behavioral sciences who exemplify the role of teacher-scholar through the integration of education and research.

- CIF21: Funding of $6.82 million will continue to support development of user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research through increased investment in the Resource Implementations for Data Intensive Research in the Social, Behavioral, and Economic Sciences (RIDIR) program. SBE will support investments in data science and infrastructure, in collaboration with the Division of Advanced Cyberinfrastructure (ACI) within the Directorate for Computer and Information Sciences and Engineering (CISE), to address critically important issues related to reproducibility and data access.

- I-Corps™: In FY 2017, SBE will maintain its investment of $500,000 in continuing support of a multi-year effort to strengthen collaboration between SBE scientists in academia and the technological, entrepreneurial, and business communities and practitioners.

- NSF INCLUDES: SBE will invest $500,000 in an NSF-wide effort to increase participation of underrepresented groups in STEM fields.

- INFEWS: SBE will continue its investment of $4.50 million in this NSF-wide initiative to enhance capacity to explore the interactions among food, energy, and water (FEW) systems by supporting well-integrated interdisciplinary research efforts to understand, model, design, and manage these interconnected systems that include the social/behavioral processes (such as decision making by and governance of individuals, organizations, and institutions) and their interactions with the FEW systems' various physical, chemical, and biological processes.

- NSF Research Traineeship (NRT): In FY 2017, SBE will increase participation (+$140,000, to a total of $640,000) in the NSF-wide NRT program, which is designed to encourage the development and implementation of bold, new, and potentially transformative models for STEM graduate education training. NRT is the successor to the Integrative Education and Research Traineeship (IGERT) program. The decrease in the above table is attributable to the final IGERT continuing grant increments in FY 2016.

- Public Access Initiative: Continued investments of $1.75 million will further NSF's efforts to make the results of the NSF-funded research available to the public.

- Risk and Resilience: SBE will continue its $4.90 million investment in CRISP to focus on the key social and behavioral research questions that are relevant for interdisciplinary perspectives on risk and resilience of social, designed, and natural systems.

- SaTC: SBE will sustain investment of $4.0 million in SaTC to support research that seeks to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity.

- Science of Science and Innovation Policy (SciSIP): SciSIP funding is held constant with the FY 2016 Estimate at $11.05 million. SciSIP will continue to support research and data collections related to innovation and R&D spending.

- Smart and Connected Communities: SBE will continue its investment of $1.50 million, in the Smart and Connected Communities activity. In partnership with CISE and the Directorate for Engineering (ENG), SBE will support research that addresses organizational, social, psychological, political, geographic, and economic issues associated with rapidly developing and evolving smart city ecosystems.

- UtB: SBE's investments in cognitive science and neuroscience and the BRAIN Initiative will remain $25.0 million, enhancing efforts to gain an integrative and comprehensive understanding of the brain and its function in context and in action. SBE will continue support of research in cognitive science at the interface of computational and engineering science and education research.

SBE Funding for Centers Programs and Facilities

SBE Funding for Centers Programs

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate	
				Amount	Percent
Total, Centers Programs	**$6.89**	**$0.13**	**$0.13**	**-**	**-**
Nanoscale Science & Engineering Centers (SES)	0.90	0.13	0.13	-	-
Science of Learning Centers (BCS, SMA)	5.99	-	-	-	N/A

Totals may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- Funding for the Nanoscale Science & Engineering Centers (NSEC) will continue at $130,000 in FY 2017 in order to maintain continuing grant increments for two centers focused on the environmental implications of nanotechnology.

SBE Funding for Facilities

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate	
				Amount	Percent
Total, Facilities	**$0.40**	**$0.40**	**$0.40**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (NNCI) (SES)	0.40	0.40	0.40	-	-

Totals may not add due to rounding.

For detailed information on individual facilities, please see the Facilities chapter.

- SBE continues support for research infrastructure through investment in the National Nanotechnology Coordinated Infrastructure (NNCI) at the FY 2016 Estimate level of $400,000.

Summary and Funding Profile

SBE supports investments in core research, education, and research infrastructure.

In FY 2017, the number of research grant proposals is projected to remain unchanged from the prior year and SBE expects to award approximately 720 research grants. The average annualized award size and award duration are estimated to remain constant with FY 2016.

In FY 2017, funding for centers accounts for less than one percent of SBE's Request. Center funding only includes support for the Nanoscale Science and Engineering Centers. FY 2017 funding for facilities accounts for less than one percent of SBE's Request and includes support for NNCI.

SBE Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,284	4,300	4,300
Number of New Awards	1,042	1,000	1,120
Funding Rate	24%	23%	26%
Statistics for Research Grants:			
Number of Research Grant Proposals	2,991	3,000	3,000
Number of Research Grants	640	640	720
Funding Rate	21%	21%	24%
Median Annualized Award Size	$111,100	$111,000	$111,000
Average Annualized Award Size	$137,400	$137,000	$137,000
Average Award Duration, in years	2.6	2.6	2.6

Program Monitoring and Evaluation

External Program Evaluations and Studies:

Workshops and Reports

- The National Center for Science and Education Statistics (NCSES), by the end of FY 2016, will have convened two review activities under the auspices of the National Research Council's Committee on National Statistics (CNSTAT) to conduct a comprehensive review of its approach to measuring the U.S. Science and Engineering (S&E) enterprise. The first, continuing through FY 2017, examines current approaches to measuring the S&E workforce and provides findings and recommendations for improving data and data collection methods. NCSES's expectation is that the information included in this report will provide the details, direction, and guidance necessary to develop a more robust and flexible framework for measuring the S&E workforce for the next decade and beyond. The second workshop, to be convened in FY 2016 on innovation activities and innovation measurement, will continue to inform the refinement and prioritization of NCSES work in innovation planning in FY 2017.
- In response to the recommendations of the SBE Advisory Committee, SES awarded funding to support the convening of a 15-month National Academies of Sciences, Engineering, and Medicine (NAS) standing committee to examine the most promising trajectories for the three major ongoing social science surveys: American National Election Studies (ANES), General Social Survey (GSS), and Panel Study of Income Dynamics (PSID). The objective is to inform NSF's FY 2017 efforts to develop options for the future of the ANES, GSS, and PSID that improve on their relevance and cost-effectiveness through assessments of the history of the surveys and the kinds of users and uses they have supported. Recommendations will provide insights about interoperability among the surveys, which represent considerable infrastructure for the SBE sciences.

- The SBE Advisory Committee Subcommittee on Replicability in Science completed and issued its report, *Social, Behavioral, and Economic Sciences Perspectives on Robust and Reliable Science*,[2] in FY 2015. The report, in conjunction with a follow-up set of specific research recommendations, will inform potential future SBE activities in this area.
- The Science of Science and Innovation Policy (SciSIP) program issued a Dear Colleague Letter (DCL) for *Agenda Setting Workshops in 2015 for the SciSIP Program*[3] to facilitate the generation and execution of a new roadmap for the Science of Science Policy community and a strategic plan for the SciSIP program. The resulting workshops, convening during FY 2016, will inform the funding priorities of SciSIP in FY 2017 and beyond.
- The Science of Learning program is hosting a Network for the Science of Learning meeting in 2016. The anticipated outcomes of this meeting will be to highlight the accomplishments of NSF investments in the science of learning and to assist in informing SBE regarding the direction and funding priorities of science of learning-related activities in FY 2017 and beyond.

Committees of Visitors (COVs)

- In 2015, COVs reviewed BCS and SMA. COV reports and SBE responses were presented to and approved by the SBE Advisory Committee in December 2015. Over the course of the next several years, the COV reports will influence both divisional operations as well as inform deliberations regarding SBE's programmatic portfolio development.
  - The SMA COV provided input regarding SMA's programs and the scientific and management aspects related to capacity building, community building, disciplinary diversity, and the adequacy of SMA's structure and resources. The COV's recommendations included exploring, with other divisions and directorates, ways to expand the capacity and infrastructure for large-scale data science; increasing outreach efforts to Minority Serving Institutions to improve the quality and number of proposals received; and strengthening the collection of long-term outcome measures for SMA-supported programs.
  - The BCS COV identified multiple key features that will define the future landscape for BCS sciences and programs by providing recommendations concerning the quality and effectiveness of the merit review process of BCS-managed programs; broadening the research portfolio of researchers and universities supported; and continuing support for and participation in broad, multi-disciplinary fields of sciences.
- In 2016, a COV will review the SES Division.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in SBE Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	1,808	1,800	1,900
Other Professionals	406	400	400
Postdoctoral Associates	309	300	300
Graduate Students	1,858	1,800	1,900
Undergraduate Students	733	700	800
Total Number of People	**5,114**	**5,000**	**5,300**

[2] www.nsf.gov/sbe/AC_Materials/SBE_Robust_and_Reliable_Research_Report.pdf
[3] www.nsf.gov/pubs/2015/nsf15047/nsf15047.pdf

DIVISION OF SOCIAL AND ECONOMIC SCIENCES (SES) $105,420,000
+$7,240,000 / 7.4%

SES Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, SES	**$98.36**	**$98.18**	**$105.42**	**$7.24**	**7.4%**
Research	**88.31**	**87.81**	**96.61**	**8.80**	**10.0%**
CAREER	2.94	3.69	3.74	0.05	1.4%
Centers Funding (total)	0.82	0.13	0.13	-	-
Nanoscale Science & Engineering Centers	0.82	0.13	0.13	-	-
Education	**2.37**	**2.97**	**1.41**	**-1.56**	**-52.5%**
Infrastructure	**7.68**	**7.40**	**7.40**	**-**	**-**
NNCI	0.40	0.40	0.40	-	-
Research Resources	7.28	7.00	7.00	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for SES is $105.42 million, of which $98.18 million is discretionary funding and $7.24 million is new mandatory funding. The mandatory funding is within the research line in the above table.

SES supports research and related activities, conducted within the U.S. and globally, that improve understanding of economic, political, and social institutions and how individuals and organizations behave within them. SES funds activities investigating risk assessment and decision-making by individuals and groups; the nature and development of science and technology and their impact on society; methods and statistics applicable across the social, economic, and behavioral sciences; scholarly career development; and broadening participation in the social, behavioral, and economic sciences. Discipline-based programs include economics, political science, and sociology, while interdisciplinary programs support fields such as decision-making and risk management; law and social sciences; methods, measurement, and statistics; science of organizations; and science, technology, and society. In many of its programs, SES is the major, if not the only, source of federal funding for fundamental research, making important investments in the data resources and methodological advances that produce transformative research.

In general, 72 percent of the SES portfolio is available for new research grants and 28 percent is available for continuing grants.

FY 2017 Summary
All funding decreases/increases represent change over the FY 2016 Estimate.

Research
Overall, support for SES disciplinary and interdisciplinary research increases (+$8.80 million, to a total of $96.61 million).

- SES will maintain support for Risk and Resilience through CRISP, which focuses on the key social and behavioral research questions that are relevant for interdisciplinary perspectives on risk and resilience of social, designed, and natural systems. SES support for this activity is held constant with the FY 2016 Estimate at $4.0 million.

- CAREER funding in FY 2017 increases by $50,000, to a total of $3.74 million. This investment is consistent with SES's emphasis on supporting early career researchers.
- CIF21 funding is maintained at $4.23 million, supporting the development of user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research. SES will continue its investments in data science, in collaboration with CISE/ACI to address critically important issues related to reproducibility and data access.
- Continued investment of $2.0 million for SaTC will support research that seeks to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity.
- Funding for SES's SBP investment is maintained at the level of $750,000. This investment supports efforts to build the scientific foundation and research evidence base needed for future broadening participation efforts. Investing in research that informs the science of broadening participation spans the SBE sciences and engages all of NSF.
- SES will continue an investment of $2.50 million in INFEWS, which will enhance capacity to explore the interactions among water, food, and energy systems.
- Funding for NSEC will continue at $130,000.
- SES will invest $750,000 in the Smart and Connected Communities activity. In partnership with ENG and CISE, and in cooperation with BCS, SES will support research that addresses organizational, social, psychological, political, and economic issues associated with rapidly developing and evolving smart city ecosystems.
- A general increase to core program investments of $8.75 million will increase funding in support of research focused on robust and reliable science; enhance support for early career investigators, and improve the overall success rate of high-quality research proposals received by SES.

<u>Education</u>

- Support for the ADVANCE program is maintained at $600,000, and REU supplements ($500,000) remain constant.
- NRT and IGERT: Funding for IGERT decreases $1.56 million, to a total of zero, as a result of final IGERT continuing grant increments. In FY 2014, IGERT was succeeded by a new program, NRT, which encourages the development of bold, new, potentially transformative, and scalable models for STEM graduate training that ensure graduate students develop the skills, knowledge, and competencies needed to pursue a range of careers within and outside academia. SES will invest $40,000 in FY 2017 in NRT, equal to the FY 2016 Estimate.
- SES will invest $250,000 in an NSF-wide effort to increase participation of underrepresented groups in STEM fields through the NSF INCLUDES program.
- In an effort to establish a better balance between the responsibilities and demands of work lives and family lives for social and behavioral scientists, SES will maintain its investment of $20,000 to support the Career-Life Balance (CLB) initiative.

<u>Infrastructure</u>

- SES will maintain its investment of $400,000 in NNCI, the successor to NNIN.
- SES research resources activities are unchanged, for a total of $7.0 million. Funding supports multi-million dollar survey awards such as the American National Election Studies (ANES), the Panel Study of Income Dynamics (PSID), and the General Social Survey (GSS). These surveys are national resources for research, teaching, and decision-making and have become models for similar undertakings in other fields. $2.0 million of the research resources funding supports SES's CIF21 investment inclusive of support for the RIDIR activity, which seeks to develop user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research.

DIVISION OF BEHAVIORAL AND COGNITIVE SCIENCES (BCS) $102,080,000 +$7,020,000 / 7.4%

BCS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, BCS	**$97.03**	**$95.06**	**$102.08**	**$7.02**	**7.4%**
Research	**92.88**	**92.25**	**99.80**	**7.55**	**8.2%**
CAREER	5.42	3.58	3.63	0.05	1.4%
Centers Funding (total)	1.71	-	-	-	N/A
Nanoscale Science & Engineering Centers	0.08	-	-	-	N/A
Science of Learning Centers	1.63	-	-	-	N/A
Education	**2.40**	**2.11**	**1.58**	**-0.53**	**-25.1%**
Infrastructure	**1.75**	**0.70**	**0.70**	**-**	**-**
Research Resources	1.75	0.70	0.70	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for BCS is $102.08 million, of which $95.06 million is discretionary funding and $7.02 million is new mandatory funding. The mandatory funding is within the research line in the above table.

BCS supports research and related activities that advance fundamental understanding in the behavioral, cognitive, anthropological, and geographic sciences. Strong core programs are complemented by active involvement in competitions that support collaborative and cross-disciplinary projects. The division seeks to advance scientific knowledge and methods focusing on human cognition and behavior, including perception, thought processes, language, learning, and social behavior across neural, individual, family, and group levels. BCS supports activities focusing on human variation in society, culture, and biology, and how these variations and related patterns develop and change across time and space. The division aims to increase basic understanding of geographic distributions and relationships as well as the capabilities to explore them, with an emphasis on interactions among human and natural systems on the Earth's surface. BCS research is helping to prepare for and mitigate the effects of natural and human-initiated disasters, predict and address how people respond to stressors, improve methods for effective learning, enhance the quality of social interaction, and respond to issues such as globalization, terrorism, and environmental change.

In general, 74 percent of the BCS portfolio is available for new research grants and 26 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

Overall, support for BCS disciplinary and interdisciplinary research increases (+$7.55 million, to a total of $99.80 million).

- Continued support of $18.60 million for UtB will further efforts to gain an integrative and comprehensive understanding of the brain and its function in context and in action.

- BCS will maintain its support, at $900,000, for Risk and Resilience through CRISP, which focuses on the key social and behavioral research questions that are relevant for interdisciplinary perspectives on risk and resilience of social, designed, and natural systems.
- CAREER funding in FY 2017 increases by $50,000, to a total of $3.63 million. This investment is consistent with BCS's emphasis on supporting early career researchers.
- CIF21 funding totals $1.50 million, to support development of user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research. BCS will enhance its investments in data science, in collaboration with CISE/ACI, to address critically important issues related to reproducibility and data access.
- Continued investment of $1.20 million is provided for SaTC to support research that seeks to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity.
- BCS will make an investment of $2.0 million in INFEWS. This investment will enhance capacity to explore the interactions among water, food, and energy systems.
- BCS support ($3.0 million) for the science of learning will fund interdisciplinary research on the science of learning.
- BCS will fund an investment of $750,000 in the Smart and Connected Communities activity. In partnership with ENG and CISE, and in cooperation with SES, BCS will support research that addresses organizational, social, psychological, political, geographic, and economic issues associated with rapidly developing and evolving smart city ecosystems.
- Funding for BCS's SBP investment is maintained at the level of $750,000. This investment supports efforts to build the scientific foundation and research evidence base needed for future broadening participation efforts.
- A general increase to core program investments of $7.50 million will support early career investigators, disciplinary and interdisciplinary research in the behavioral and cognitive sciences and improve the funding rate for highly meritorious research proposals received by BCS.

Education

- BCS support for the ADVANCE program is maintained at $400,000.
- REU supplements funding remains constant at $440,000.
- NRT and IGERT: Funding for IGERT decreases $530,000, to a total of zero, as a result of final IGERT continuing grant increments. In FY 2014, IGERT was succeeded by NRT, which encourages the development of bold, new, potentially transformative, and scalable models for STEM graduate training that ensure that graduate students develop the skills, knowledge, and competencies needed to pursue a range of careers within and outside academia. BCS will invest $460,000 in FY 2017 in NRT, level with the FY 2016 Estimate.
- BCS will invest $250,000 in an NSF-wide effort to increase participation of underrepresented groups in STEM fields through the NSF INCLUDES program.
- In an effort to establish a better balance between the responsibilities and demands of work lives and family lives for social and behavioral scientists, BCS will maintain its investment of $30,000 to support the CLB initiative.

Infrastructure

- FY 2016 support for infrastructure activities is continued at $700,000. Funding supports BCS's CIF21 investment inclusive of support for the RIDIR competition, which seeks to develop user-friendly, large-scale, next- generation data resources and relevant analytical techniques to advance fundamental SBE research.

NATIONAL CENTER FOR SCIENCE AND ENGINEERING STATISTIC (NCSES) — $51,760,000 +$1,000,000 / 2.0%

NCSES Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, NCSES	**$50.94**	**$50.76**	**$51.76**	**$1.00**	**2.0%**
Infrastructure	**50.94**	**50.76**	**51.76**	**1.00**	**2.0%**

Totals may not add due to rounding.

The FY 2017 Budget Request for NCSES is $51.76 million, which is entirely discretionary funding.

NCSES was established within the National Science Foundation by Section 505 of the America COMPETES Reauthorization Act of 2010 (P.L. 111-358). The Act provides NCSES with the legislative mission to "…serve as the central federal clearinghouse for the collection, interpretation, analysis, and dissemination of objective data on science, engineering, technology, and research and development." NCSES is called on to support the collection of statistical data on research and development trends, the science and engineering workforce, U.S. competitiveness, and the condition and progress of the Nation's STEM education; to support research using the data it collects and on methodologies in areas related to the work of the Center; and to support the education and training of researchers in the use of its own and other large-scale, nationally representative data sets.

As one of the thirteen principal federal statistical agencies, NCSES has broad responsibility for statistics regarding the science and engineering enterprise. NCSES designs, supports, and directs a coordinated collection of periodic national surveys and performs a variety of other data collections and research, providing policymakers, researchers, and other decision-makers with high quality data and analysis on R&D, innovation, the education of scientists and engineers, and the science and engineering workforce. The work of NCSES involves survey development, methodological and quality improvement efforts, data collection, analysis, information compilation, dissemination, web access, and customer service to meet the statistical and analytical needs of a diverse user community. It prepares two congressionally mandated biennial reports — Science and Engineering Indicators (SEI) and Women, Minorities, and Persons with Disabilities in Science and Engineering. The data collected by NCSES serve as an important resource for researchers in SBE's SciSIP program.

The funding portfolio for NCSES includes ongoing, cyclical surveys; data, reports and other products; and projects accomplished primarily through contracts and grants.

FY 2017 Summary
All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Infrastructure</u>
In FY 2017, support for NCSES infrastructure activities increases by $1.0 million, to an overall total of $51.76 million. Funding at this level maintains NCSES' core programmatic activities and supports significant targeted improvements in NCSES's statistical and analytic programs.

The additional resources will be used to provide continued support for (1) developing enhanced data access tools, techniques, and visualizations; (2) new data collection techniques building on administrative data and other "big data" sources; and (3) questionnaire redesign and survey improvements supporting current research, policy, and community needs, such as improved data on pathways for scientists and engineers and measures of innovation.

SBE OFFICE OF MULTIDISCIPLINARY ACTIVITIES (SMA) $29,510,000
+$1,310,000 / 4.6%

SMA Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, SMA	**$29.86**	**$28.20**	**$29.51**	**$1.31**	**4.6%**
Research	**20.70**	**19.60**	**20.77**	**1.17**	**6.0%**
CAREER	0.17	-	-	-	N/A
Centers Funding (total)	4.36	-	-	-	N/A
Science of Learning Centers	4.36	-	-	-	N/A
Education	**6.87**	**5.95**	**6.09**	**0.14**	**2.4%**
Infrastructure	**2.29**	**2.65**	**2.65**	**-**	**-**
Research Resources	1.47	0.90	0.90	-	-
Research Resources - Public Access Initiative	0.82	1.75	1.75	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for SMA is $29.51 million, of which $27.41 million is discretionary funding and $2.10 million is new mandatory funding. The mandatory funding is within the research line in the above table.

SMA provides a focal point for programmatic activities that cut across SBE and NSF disciplinary boundaries. SMA houses three programs: Science of Science and Innovation Policy (SciSIP), Research Experiences for Undergraduates (REU) Sites, and SBE Postdoctoral Research Fellowships (SPRF). SMA will play a critical role in several NSF areas of emphasis in FY 2017: UtB, cyberinfrastructure and computer science, via CIF21; cybersecurity, via SaTC; innovation, via I-Corps™; interdisciplinary research and training, via activities such as the SPRF-IBSS track; and the science of learning. These investments reflect newly requested funds and a redeployment of resources previously committed to other cross-directorate and NSF-wide priority activities. Co-funding with other divisions in SBE and with other directorates is typical for SMA. While all SBE divisions pursue interdisciplinary work, SMA assists with seeding multidisciplinary activities for the future. All areas of SBE sciences are represented in the SMA portfolio.

In general, 61 percent of the SMA portfolio is available for new research grants and 39 percent is available for continuing grants.

FY 2017 Summary
All funding decreases/increases represent change over the FY 2016 Estimate.

<u>Research</u>
Overall, support increases for basic research activities (+$1.17 million, to a total of $20.77 million).
- SMA will fund integrative, interdisciplinary research in the science of learning ($2.0 million).
- Support for UtB is maintained at $6.40 million in order to enhance efforts to gain an integrative and comprehensive understanding of the brain and its function in context and in action.
- Investment in I-Corps™ is maintained at $500,000.
- Funding for the SciSIP disciplinary research activities is constant at $6.10 million.

- With a continued investment of $800,000, SMA will partner with CISE in devoting resources to the SaTC initiative through support for research that seeks to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity. This investment will support research at the interstices of the economic and computer sciences to achieve secure practices through market mechanisms and behavioral incentives.
- CIF21 support is held constant at $1.09 million, for investments in data science, to address critically important issues related to reproducibility and data access.
- SMA will redeploy its $1.0 million from the final year of the INSPIRE program to other core and crosscutting activities such as robust and reliable research in FY 2017.

Education

Support for education activities in SMA will increase.

- SMA investments in the Research Experiences for Undergraduates (REU) Sites ($2.89 million) and REU supplement ($60,000) programs are maintained. Funding will support research experiences for students by providing appropriate and valuable educational experiences for undergraduate students through their participation in research.
- The SBE Postdoctoral Research Fellowship (SPRF) has two tracks: broadening participation (SPRF-BP) and interdisciplinary behavioral and social science research (SPRF-IBSS). FY 2017 Request funding for these programs is unchanged at $1.50 million for each activity.
- SMA will initiate an investment of $140,000 in support of the NRT program, which encourages the development of bold, new, potentially transformative, and scalable models for STEM graduate training that ensure that graduate students develop the skills, knowledge, and competencies needed to pursue a range of careers within and outside academia.

Infrastructure

- Continued investment of $1.75 million in NSF's Public Access Initiative will support efforts to make NSF-funded research available to the public, including developing outreach and guidance materials.
- Support for research resources is held constant at $900,000. Funding supports SMA's CIF21 investment inclusive of support for the RIDIR competition, which seeks to develop user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research.

OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE) $52,050,000, +$2,950,000 / 6.0%

OISE Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
OISE	**$48.46**	**$49.10**	**$52.05**	**$2.95**	**6.0%**

Totals may not add due to rounding.

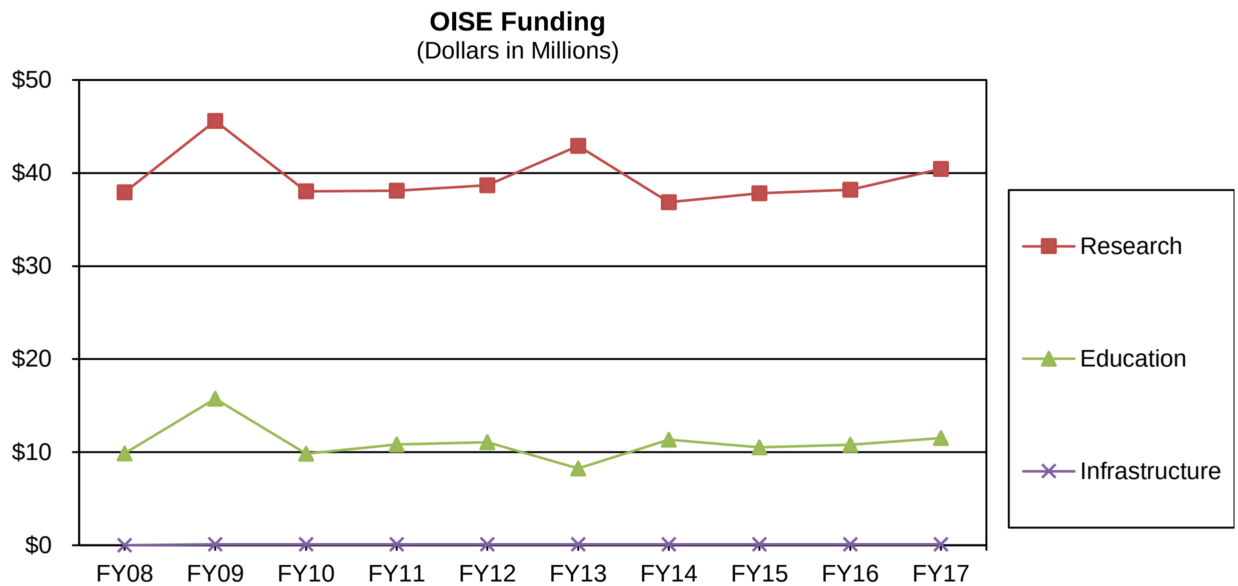
The FY 2017 Budget Request for OISE is $52.05 million, of which $49.10 million is discretionary funding and $2.95 million is new mandatory funding. The major focus of OISE's mandatory funding is to support core programs, e.g., Partnerships in International Research and Education (PIRE), International Research Experiences for Students (IRES), and/or increase co-funding with directorates through Global Venture Fund (GVF). Within core program activities, OISE mandatory funding will emphasize increasing the number of early career investigators and/or advance data- and computational-intensive areas.

About OISE

OISE facilitates international science and engineering activities across NSF. OISE does this by promoting an integrated, Foundation-wide international strategy that is innovative, catalytic, and responsive to a broad range of NSF and national interests. This strategy focuses on leveraging NSF and international resources to drive transformative science and engineering research. In FY 2017, OISE will focus on enhancing its analysis, reporting, and evaluation capabilities to ensure that NSF pursues international efforts in a strategic manner.

NSF, with support from OISE, engages internationally by investing in people, driving research priorities, partnering on facilities and infrastructure, and creating leadership opportunities in international fora. OISE's FY 2017 Budget Request supports this strategy by 1) focusing on targeted programs, such as PIRE and IRES; 2) by providing expert analysis, and 3) by maintaining a network of international counterpart agencies and other organizations that can be accessed to promote common interests.

OISE also manages NSF's overseas offices in Beijing, Brussels, and Tokyo. These offices report on and analyze in-country and regional science and technology developments and policies, promote greater collaborations between U.S. and foreign researchers, liaise with foreign counterpart agencies and research institutions, and facilitate coordination and implementation of NSF research and education programs.



FY 2009 reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary

OISE Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, OISE	**$48.46**	**$49.10**	**$52.05**	**$2.95**	**6.0%**
Research	37.84	38.20	40.45	2.25	5.9%
Education	10.52	10.80	11.50	0.70	6.5%
Infrastructure	0.10	0.10	0.10	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for OISE is $52.05 million, of which $49.10 million is discretionary funding and $2.95 million is new mandatory funding. All mandatory funding will support activities included within the Research line in the above table.

Research

- In FY 2017, OISE will invest $40.45 million, $2.25 million above the FY 2016 Estimate, in research programs to promote NSF's international engagement strategy. These funds will be used to support international partnerships and leverage research investments made in other parts of the Foundation to advance U.S. fundamental science and engineering.
- Research programs funded in FY 2017, including the Global Venture Fund (GVF), support a broad range of collaborative activities (workshops, planning grants, and international research) with NSF's research and education directorates.
- OISE will support a new set of awards and continue support for existing awards in the PIRE program, which leverages NSF's resources with those of numerous foreign science and technology funding agencies. In FY 2017, PIRE will be funded at $21.95 million, or $4.54 million above the FY 2016 Estimate.

- The FY 2017 Request will support $1.76 million for clean energy research, of which $1.28 million will fund the Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) program. These investments will enable U.S. scientists and engineers to partner with their international colleagues in these high priority areas.

Education
- OISE supports international research and education activities for U.S. undergraduate students, graduate students, and post-doctoral fellows through the International Research experiences for Students (IRES), East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI) and International Research Fellowship Programs (IRFP) activities, respectively. The total OISE FY 2017 funding for these programs is $11.50 million.
- In FY 2017, the EAPSI Request of $2.50 million, or $700,000 above the FY 2016 Estimate, will support a contract to better use staff resources for project implementation support.

Infrastructure
- In FY 2017, OISE maintains a $100,000 investment in the National Nanotechnology Coordinated Infrastructure (NNCI) program. The NNCI advances U.S. efforts to advance nanoscience research and education. For detailed information about NNCI, see the Facilities chapter.

Major Investments

OISE Major Investments
(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Clean Energy Technology	$16.45	$5.51	$1.76	-$3.75	-68.1%
INFEWS	-	1.28	1.28	-	-
SEES	16.45	4.23	0.48	-3.75	-88.7%
Understanding the Brain	-	0.59	0.59	-	-

Major investments may have funding overlap and thus should not be summed.

- Clean Energy Technology (-$3.75 million, to a total of $1.76 million): OISE will fund international collaborations for clean energy technology research. OISE's clean energy support consists of funding to the INFEWS and Science, Engineering, and Education for Sustainability (SEES) priority areas. As a result of planned sunsetting of the SEES program, Clean Energy and SEES decrease by $3.75 million. OISE's SEES funding will cover residual outyear commitments associated with SEES awards made in FY 2012.

- INFEWS ($1.28 million, equal to the FY 2016 Estimate): OISE will invest in international INFEWS collaborations through co-funding the U.S. institutions involved in the research selected by NSF directorates.

- Understanding the Brain (UtB) ($590,000, equal to the FY 2016 Estimate): OISE will co-fund UtB proposals selected by NSF research directorates when they contain an international collaboration. OISE co-funding will go to the U.S. institution involved in the collaboration.

Summary and Funding Profile

OISE supports investment in research, education, and research infrastructure. A shift in emphasis from small-scale to larger-scale catalytic activities began in FY 2015, resulting in an increase in the number of proposals and awards and an increase in the median award size. These trends will continue in FY 2017 as OISE focuses on funding projects that are larger-scale with greater impacts. OISE will also continue co-funding meritorious science and engineering projects submitted to other NSF directorates. FY 2017 increases in the average award size and duration reflect primarily the start of a new cohort of 5-year PIRE awards.

OISE Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	604	600	620
Number of New Awards	297	300	310
Funding Rate	49%	50%	50%
Statistics for Research Grants:			
Number of Research Grant Proposals	387	390	420
Number of Research Grants	80	80	90
Funding Rate	21%	21%	21%
Median Annualized Award Size	$83,000	$84,000	$89,000
Average Annualized Award Size	$247,526	$110,000	$280,600
Average Award Duration, in years	2.7	2.2	2.8

Program Monitoring and Evaluation

<u>External Program Evaluations and Studies</u>

- In FY 2016, OISE will initiate an evaluation of IRES and EAPSI. Results will be incorporated into an analysis of the OISE program portfolio to ensure OISE is supporting the most effective balance of programs. Any portfolio rebalancing will target programs in the most strategic areas to leverage resources to benefit NSF and the United States and advance global science and engineering research. Final results from the EAPSI and IRES evaluations are expected in FY 2017. The portfolio analysis will be complete in FY 2017.

- An evaluation of the PIRE program was performed by an independent contractor to investigate how the international emphasis of PIRE provided an impact different from other NSF grants in programs without an international emphasis. The report was delivered to OISE in FY 2016.[1]
  - The evaluation findings include that with respect to:
    - Research outcomes: PIRE journal articles have an above average citation impact and a significantly higher mean percentage of foreign contributors per paper than non-PIRE articles.
    - Participant-level research outcomes: PIRE postdocs and graduate students produced more annual publications post-onset than non-PIRE postdocs and graduate students, and PIRE postdocs' publications had significantly higher citation impact per year than non-PIRE postdocs' publications. Significantly higher percentages of PIRE participants than non-PIRE participants traveled abroad for their project, and high percentages of PIRE participants

[1] http://abtassociates.com/AbtAssociates/files/54/541407a8-485e-4f5d-8697-bb17542544e8.pdf

collaborated with foreign personnel. Post PIRE, high percentages of PIRE PIs and graduate students continued to collaborate with foreign researchers after the project had ended. While it is noteworthy that PIRE positively affected the research productivity of both postdoctoral researchers and graduate students, it did not affect the productivity of PIs.

- Therefore, one of the evaluation's recommendations is that NSF consider requiring PIRE projects to fund a project administrator to help manage the projects and thus allow the PIs to focus on the research agenda of the award. In response, OISE is developing a revised solicitation for the FY 2016 PIRE announcement which will incorporate this recommendation.

Committees of Visitors (COV)

- In 2017, a COV will review proposals from all OISE programs.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in OISE Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	487	490	520
Other Professionals	61	60	70
Postdoctoral Associates	184	190	200
Graduate Students	168	170	180
Undergraduate Students	123	130	130
Total Number of People	**1,023**	**1,040**	**1,100**

INTEGRATIVE ACTIVITIES (IA) $459,860,000

+$12,800,000 / 2.9%

IA Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
EPSCoR	$165.46	$160.00	$170.69	$10.69	6.7%
Graduate Research Fellowships	166.72	165.96	166.08	0.12	0.1%
INSPIRE	10.89	13.75	-	-13.75	-100.0%
Major Research Instrumentation	74.28	75.69	90.00	14.31	18.9%
NSF INCLUDES	-	1.88	1.88	-	-
Planning and Policy Support[1]	[0.95]	[1.35]	1.43	[1.43]	N/A
Research Investment Communications (RIC)	3.14	3.14	3.14	-	-
Science & Technology Centers Class of 2016	-	20.00	20.00	-	-
Science & Technology Centers Administration	1.23	0.90	0.90	-	-
Science & Technology Policy Institute	4.74	4.74	4.74	-	-
STAR METRICS	1.00	1.00	1.00	-	-
Total, IA	**$427.46**	**$447.06**	**$459.86**	**$12.80**	**2.9%**

Totals may not add due to rounding.

[1] Planning and Policy Support funding for FY 2015 and FY 2016 is displayed for comparability. FY 2015 and FY 2016 activities are supported by the Other Program Related Administration. See the Program Accounts: R&RA and EHR chapter for more information.

The FY 2017 Budget Request for Integrative Activities (IA) is $459.86 million, of which $451.30 million is discretionary funding and $8.56 million is new mandatory funding. The mandatory funding will support Experimental Program to Stimulate Competitive Research (EPSCoR) activities, with particular emphasis on 1) enhancing the development of a diverse group of high-quality early career investigators, and 2) strengthening interdisciplinary research collaborations across EPSCoR jurisdictions and more broadly in the research community. Examples of EPSCoR activities in these areas include an EPSCoR Research Fellows component for early career faculty under the Research Infrastructure Improvement (RII) activities and the expansion of the RII Track-2: Focused EPSCoR Collaborations with increased emphasis on the development of a diverse group of academic leaders in NSF priority areas.

About IA

IA builds capacity across NSF research and education communities through long-lived “flagship” programs, such as Science and Technology Centers (STCs) and Major Research Instrumentation (MRI); strengthens the science and engineering enterprise throughout the U.S. through EPSCoR; develops human capital through the Graduate Research Fellowship (GRF) program; and develops the NSF-wide evaluation and assessment capability (EAC).

The FY 2017 Budget Request will support research in both the Administration’s and NSF’s priority areas, including clean energy and Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS). The Office of Integrative Activities (OIA) will co-lead activities with the Directorates for Education and Human Resources (EHR) and Engineering (ENG) in NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science), a comprehensive national initiative to enhance U.S. leadership in science and engineering discovery and innovation by proactively seeking and developing science, technology, engineering and mathematics (STEM) talent from all sectors and groups in our society.

FY 2017 Summary

All funding changes are over the FY 2016 Estimate.

- EPSCoR (+$10.69 million, to a total of $170.69 million) funding in FY 2017 will catalyze key research themes, including national research priorities within and among EPSCoR jurisdictions that empower knowledge generation, broaden participation in science and engineering, and strengthen the research opportunities available to early career faculty.

- The GRF program invests (+$120,000, to a total of $166.08 million) in the U.S. science and engineering (S&E) human capital development necessary to ensure the Nation's leadership in STEM research and innovation through the selection and support of outstanding U.S. graduate students. IA provides 50 percent of NSF's funding for GRF, with the remainder provided by the Directorate for Education and Human Resources (EHR). For additional information on GRF, see the discussion on Major Investments in STEM Graduate Education narrative in the NSF-Wide Investments section.

- Dedicated funding is not necessary to encourage the kinds of projects supported through INSPIRE. Starting in FY 2017, each directorate will continue support for INSPIRE-like interdisciplinary research through core and cross-cutting programs, coordinating with other directorates and divisions, as necessary, for internal review of these projects. NSF anticipates developing a new funding mechanism that will manifest many of the principles of INSPIRE. This new funding mechanism will have guidelines published in the annual NSF Grants Proposal Guide, and will be available to any researcher conducting transformational, interdisciplinary research in fields that NSF supports. Therefore, in FY 2017, IA INSPIRE co-funding is eliminated.

- The MRI program (+$14.31 million, to a total of $90.0 million) will continue to catalyze new knowledge and discoveries by empowering the Nation's scientists and engineers with state-of-the-art research instrumentation. The MRI program supports instrument acquisition or development, such as microscopes, spectrometers, cyberinfrastructure, genome sequencers, or telescopes. MRI also supports research-intensive learning environments that promote the development of a diverse workforce as well as facilitates academic and private sector partnerships. The FY 2017 funding level will support roughly 190 MRI awards.

- NSF INCLUDES' (no change, to a total of $1.88 million) goal is to develop the STEM talent of women, members of racial and ethnic groups that have been underrepresented in STEM, and people with disabilities.

- Planning and Policy Support funding in FY 2017 is $1.43 million. This budget line is being established to support certain NSF-wide policy and planning activities. This includes support for workshops on long-term foundational research and education questions. It also includes certain activities previously supported through other program related administration, including annual agency awards (the Vannevar Bush Award, Public Service Award, Alan T. Waterman Award, and National Medal of Science), and several summer science internship programs that target science, technology, engineering, and mathematics students from underrepresented groups. The FY 2017 Budget Request will also fund NSF collaborations with the National Academies of Science, including the Government-University-Industry

Research Roundtable,[1] and the Committee on Science, Engineering, and Public Policy.[2]

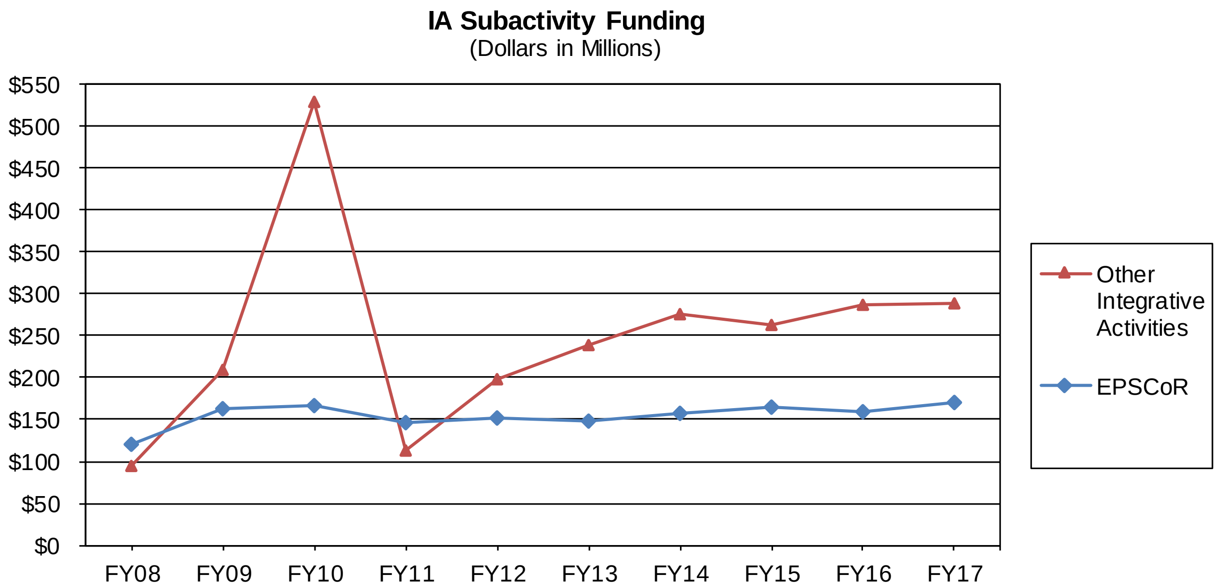
- Research Investment Communications (RIC) funding in FY 2017 is $3.14 million, equal to the FY 2016 Estimate. RIC is a leading-edge communications effort that is essential for public awareness and support of science and engineering. RIC creates products and processes through traditional and social media platforms that make NSF's investments in science, technology, engineering, education, and mathematics readily available and easily understandable to everyone. In FY 2017, RIC will continue its focus on informing policy makers, the media, and the general public about the impact of NSF's investments on their daily lives and the Nation's future.

- The Science and Technology Centers: Integrative Partnerships (STC) (no change, to a total of $20.90 million) program supports innovative, potentially transformative, complex research and education projects that require large-scale, long-term awards. STCs engage the Nation's intellectual talent through partnerships among academia, industry, national laboratories, and government. These collaborations create synergies that enhance the training of the next generation of scientists, engineers, and educators; and the creation of job opportunities. STCs have impressive records of research achievements as well as fostering strong partnerships with industry. The FY 2017 Request will provide continuing support of four centers established through the 2016 STC cohort as well as post award management for each of the 12 centers.

- The Science and Technology Policy Institute (STPI) (no change, to a total of $4.74 million) is a Federally Funded Research and Development Center (FFRDC) sponsored by NSF on behalf of the White House Office of Science and Technology Policy (OSTP). STPI provides analysis of significant domestic and international science and technology policies and developments for OSTP and other federal agencies.

- Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness, and Science (STAR METRICS) (no change, to a total of $1.0 million) is an interagency pilot activity that represents a new approach to developing information on how NSF and other federal Research and Development (R&D) investments affect the innovation ecosystem. Funding will enable NSF to meet commitments to the interagency STAR METRICS partnership, promote the integration of elements of STAR METRICS into developing an assessment and evaluation information system linked to NSF's management information systems, and support assessment and evaluation pilots in NSF programs using STAR METRICS tools.

[1] http://sites.nationalacademies.org/pga/guirr/index.htm
[2] http://sites.nationalacademies.org/pga/cosepup/index.htm



FY 2009 reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

Program Monitoring and Evaluation

<u>External Program Evaluations and Studies</u>

- In FY 2014, IA initiated an evaluation of the INSPIRE program to develop and execute a formative evaluation to test whether the process is one conducive to achieve program and portfolio-level goals. Two formative evaluations are being conducted for INSPIRE. Final results from these studies are expected in September 2016.

- In 2014, two independent studies of EPSCoR were completed by the National Academy of Sciences (NAS) and the Science and Technology Policy Institute (STPI). The National Academy of Sciences study was conducted on all federal agencies that administer an EPSCoR or a program similar to the EPSCoR. The study focused on program eligibility, program focus, merit review process, and evaluation. This study was conducted by NAS' Committee on Science, Engineering, and Public Policy. The Science and Technology Policy Institute (STPI) study focused on the NSF's current eligibility criterion for jurisdictions and recommendations for better targeting available funding to those jurisdictions for which the EPSCoR program can provide the largest incremental benefit to their research infrastructure. NSF's response to the findings and recommendations of the NAS and STPI reports was transmitted to congressional staff by the Office of Legislative and Public Affairs (OLPA) and posted on the NSF EPSCoR website.[3] In response to recommendations:
  - EPSCoR has added more focus on the development of early career faculty in the RII Track-2 activities.
  - EPSCoR is working with the Evaluation and Assessment Capability (EAC) Section to outline the next phase of program evaluation (target is August 2016).
  - NSF has requested that the EPSCoR Interagency Coordinating Committee provide recommendations for EPSCoR eligibility options for further consideration by the Foundation (target is September 2016).

[3] www.nsf.gov/epscor

- In FY 2016,
  - The results of the formative evaluation for the Career Life Balance initiative will be released in September 2016.
  - EAC has four (4) evaluative/monitoring activities underway, each of which is summarized below:
    - Graduate Research Fellowship Program (GRFP). This activity encompasses the development and piloting, of a survey instrument and survey process that may be used as a permanent longitudinal monitoring system to assess program outcomes. The data tracking is being conducted by National Opinion Research Center (NORC) at the University of Chicago. Results are expected to be used to track the careers of the fellows. Final results from this pilot data collection for monitoring longitudinal career outcomes of fellowship recipients are expected in FY 2018.
    - Research Experience for Undergraduates (REU). The purpose of this project is: (1) to develop a framework for evaluating the REU Sites program, and (2) to build, pilot, test, and present findings for a web-based longitudinal data collection system that can be used, initially, to track REU Site participants, but can be adapted to measure participant outcomes. Final results are expected in FY 2019.
    - NSF Innovation Corps (I-Corps™) Teams Program. The I-Corps™ program has gained national visibility as a model for nurturing innovation and, as such, there is an increased need for assessing and quantifying the impact of this NSF investment on society. In particular, NSF is interested in evaluating the impact the I-Corps™ team program has had on team members themselves as well as on their academic organizations. A rigorous longitudinal outcome/impact evaluation of the I-Corps™ Teams program is being conducted with results expected in FY 2017.
    - Science, Engineering and Education for Sustainability (SEES). NSF has awarded a contract to conduct an evaluation of the SEES portfolio, which is scheduled to sunset in FY 2017. In FY 2015, NSF exercised its option year; thus, the final results are now expected in early FY 2017. The evaluation is designed to determine NSF's success in achieving program- and portfolio-level goals. The evaluation seeks specifically to measure the success of SEES in terms of:
      - the development of new knowledge and concepts that advance the overarching goal of a sustainable human future;
      - new and productive connections made between researchers in a range of disciplines; and
      - the development of a workforce capable of meeting sustainability challenges.

- In FY 2017, EAC will launch evaluations of INFEWS, Understanding the Brain (UtB), and NSF INCLUDES.

<u>Committees of Visitors (COV)</u>
In 2015, COV reviewed the EPSCoR program and found no program areas in need of significant improvement. The COV presented their report to the NSF Director with nine recommendations. The COV's recommendations and NSF's response were published in late FY 2015.[4]

- In 2016, a COV will review the MRI program. (The last MRI COV was convened in FY 2010.)
- In 2017, a COV will review the STC program. (The last STC COV was convened in FY 2011.)

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

[4] http://nsf.gov/od/oia/activities/cov/oia/2015/Response-to-2015-COV-Recommendations.pdf

EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCOR) $170,690,000 +$10,690,000 / 6.7%

EPSCoR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, EPSCoR	**$165.46**	**$160.00**	**$170.69**	**$10.69**	**6.7%**
Research Infrastructure Improvement (RII)	137.44	128.00	138.56	10.56	8.3%
Co-Funding	27.55	30.00	30.13	0.13	0.4%
Outreach and Workshops	0.47	2.00	2.00	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for EPSCoR is $170.69 million, of which $162.13 million is discretionary funding and $8.56 million is new mandatory funding. The FY 2017 mandatory funding is within the RII line in the above table, this funding will target EPSCoR Research Fellows and an expansion of the RII Track-2 Focused EPSCoR Collaborations in NSF priority areas.

EPSCoR assists NSF in its statutory function "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education." EPSCoR seeks to advance excellence in science and engineering research and education to achieve sustainable increases in research, education, and training capacity and competitiveness that will enable EPSCoR jurisdictions to have increased engagement in the science and engineering supported by NSF.

In FY 2016, the EPSCoR Interagency Coordinating Committee was tasked with examining the eligibility criteria across the five agencies with active programs (Department of Energy (DOE), National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH), NSF, and U.S. Department of Agriculture (USDA)) and to determine if there should be a common federal EPSCoR eligibility criterion. A summary of recommendations is targeted for July 2016.

EPSCoR uses three strategic investment tools: Research Infrastructure Improvement (RII) awards, Co-Funding, and Outreach/Workshops.

FY 2017 Summary

All funding increases represent change over the FY 2016 Estimate.

<u>Research Infrastructure Improvement (RII)</u>

- RII (+$5.69 million, to a total of $133.69 million) awards support development of physical, human, and cyber-based research infrastructure in EPSCoR jurisdictions with emphasis on collaborations among academic researchers, the private sector, and state and local governments to affect sustainable improvements in research infrastructure. These awards are designed to improve the research competitiveness of jurisdictions by strengthening their academic research infrastructure in areas of science and engineering supported by NSF and critical to the particular jurisdiction's science and technology initiative or plan. RII awards also increase the participation of underrepresented groups in STEM and enable broader regional and topical collaborations among jurisdictions and facilitate the enhancement of discovery, learning, and economic development of EPSCoR jurisdictions. The RII portfolio consists of projects addressing all three components of the food-energy-water nexus, renewable energy, and nanomaterials. In addition, it contains collaborative inter-jurisdictional projects focused on NSF priorities such as UtB and INFEWS.

Co-Funding

- Co-funding (+$5.0 million to a total of $35.0 million): EPSCoR co-invests with NSF directorates and offices on meritorious proposals from individual investigators, groups, and centers in EPSCoR jurisdictions that are submitted to the Foundation's research and education programs, and to crosscutting initiatives such as clean energy and INFEWS. These proposals are merit reviewed in NSF disciplinary programs and recommended for award, but cannot be funded without the combined, leveraged support of EPSCoR. Through co-funding, EPSCoR co-invests in NSF strategic priority areas as well as early investigator development (e.g., the Faculty Early Career Development Program (CAREER)).

Outreach and Workshops

- The Outreach and Workshops (no change from the FY 2016 Estimate of $2.0 million) component of EPSCoR solicits requests for workshops, conferences, and other community-based activities designed to explore opportunities in emerging areas of science and engineering, and to share best practices in strategic planning, diversity, communication, cyberinfrastructure, evaluation, and other capacity-building areas of importance to EPSCoR jurisdictions. EPSCoR also supports outreach travel that enables NSF staff from all directorates and offices to directly engage and inform the EPSCoR research community about NSF opportunities, priorities, programs, and policies.

Number of People Involved in EPSCoR Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate Total
Senior Researchers	579	600	600
Other Professionals	267	300	300
Postdoctoral Associates	72	70	70
Graduate Students	894	900	900
Undergraduate Students	488	500	500
K-12 Teachers	5,320	5,100	5,500
K-12 Students	97,128	94,000	100,300
Total Number of People	**104,748**	**101,470**	**108,170**

UNITED STATES ARCTIC RESEARCH COMMISSION (USARC) — $1,430,000 +$0 / 0.0%

USARC Funding

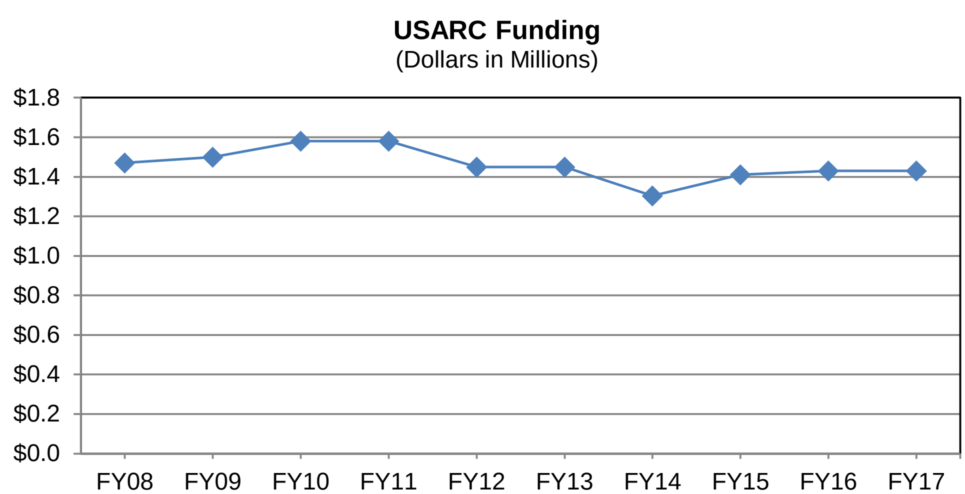
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
USARC	**$1.41**	**$1.43**	**$1.43**	**-**	**-**

About USARC

USARC was created by the Arctic Research and Policy Act of 1984, (as amended, P. L. 101-609), to assist in establishing the national policy, priorities, and goals necessary to construct a federal program plan for basic and applied scientific research with respect to the Arctic. This request provides funds to advance Arctic research, to recommend Arctic research policy, and to communicate research and policy recommendations. In addition, USARC advises the Interagency Arctic Research Policy Committee (IARPC) in developing national Arctic research projects and a five-year plan to implement those projects. USARC also supports interaction with Arctic residents, international Arctic research programs and organizations, and local institutions, including regional governments, in order to obtain the broadest possible view of Arctic research needs. USARC is an independent federal agency, funded through NSF's appropriation, specifically as an activity in the Research and Related Activities account.

The USARC is requesting $1.43 million, equal to the FY 2016 Estimate level. The FY 2017 Request will support three FTE funded at USARC. In addition, the FY 2017 Request supports one full-time contractor and four part-time contractors. A total of seven compensated personnel are authorized per P.L. 101-609. The seven Commissioners may also receive up to 90 days of salary per year, at the Executive Schedule Level IV.



EDUCATION AND HUMAN RESOURCES (EHR) $952,860,000
+$72,860,000 / 8.3%

EHR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	$227.20	$222.75	$249.28	$26.53	11.9%
Division of Graduate Education (DGE)	286.14	278.48	305.26	26.78	9.6%
Division of Human Resource Development (HRD)	143.90	150.23	155.89	5.66	3.8%
Division of Undergraduate Education (DUE)	229.08	228.54	242.43	13.89	6.1%
Total, EHR	**$886.33**	**$880.00**	**$952.86**	**$72.86**	**8.3%**

Totals may not add due to rounding.

The FY 2017 Budget Request for EHR is $952.86 million, of which $898.87 million is discretionary funding and $53.99 million is new mandatory funding. The major focus of the mandatory funding is support for STEM education core activities, with special emphasis on advancing computational- and data-intensive areas, principally through the support of early career investigators likely to be receptive to interdisciplinary and technology-intensive approaches to education. Examples of EHR activities in these areas include research initiation support for early career investigators, and cross-over investigators from STEM research to STEM education research that:

- Exploits the growing technological and data cyberinfrastructure particularly for initiatives tied to computational and inferential thinking in data science;
- Improves human capacity in cybersecurity;
- Develops and evaluates computer science coursework and instructional practices tied to the scientific and engineering disciplines; and
- Leads to transformative research on STEM learning and learning environments, broadening participation, and workforce development.

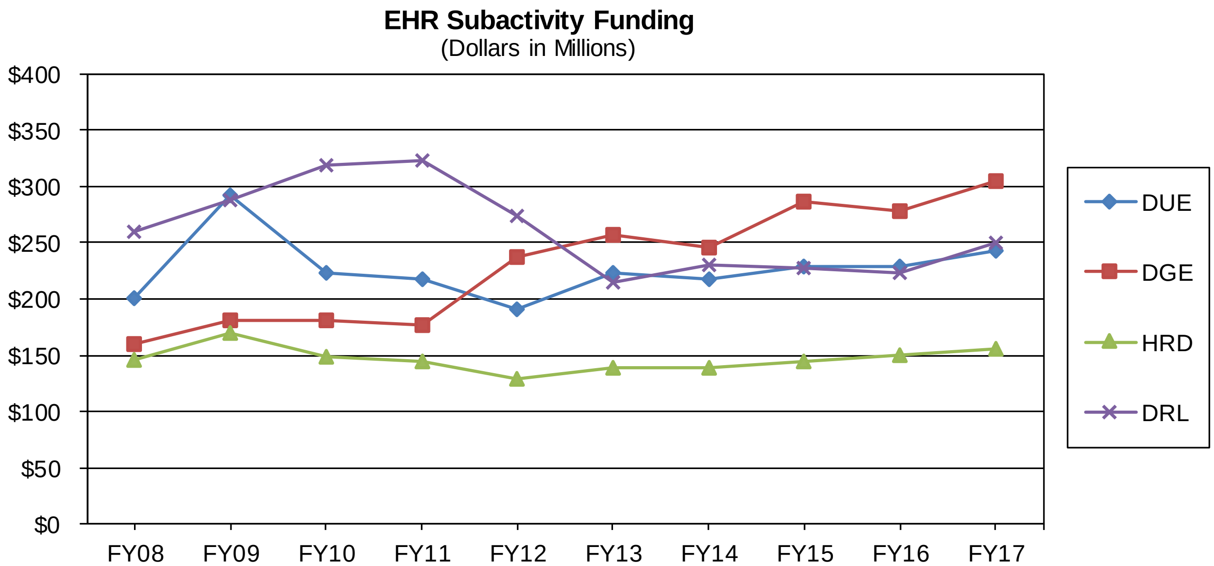
About EHR

The mission of the Directorate for Education and Human Resources (EHR), to provide the research foundation to develop a diverse, science, technology, engineering, and mathematics (STEM) literate public and workforce ready to advance the frontiers of science and engineering for society, has guided and shaped EHR's portfolio and priorities for more than 60 years. While the EHR mission remains constant, the context in which this mission is enacted changes. Each decade brings new challenges and opportunities.

The federal investment in STEM education, and within it the focused investment in STEM education research based at NSF, must anticipate and respond to changes in: population demographics and diversity; economic conditions; the nature and practices of science and engineering; and the data- and cyber-infrastructure that is transforming society, security, and the nature of research.

The progress of science and engineering depends on the education of discoverers —those who will be the leaders and innovators in science and engineering. These discoverers will become part of the STEM and STEM-related workforce, including public and private sector, academic, policy, research, and teaching occupations. The progress of science and engineering also depends on a public that values and participates in the STEM enterprise through formal and informal education, STEM-related aspects of their work, public participation in scientific research, and civic engagement.

The opportunities made possible by federal investments in STEM must be provided effectively to, and draw from, the full and diverse talent pool of the Nation.



FY 2009 funding reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

Appropriations Language

For necessary expenses in carrying out science, mathematics and engineering education and human resources programs and activities pursuant to the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), including services as authorized by section 3109 of title 5, United States Code, authorized travel, and rental of conference rooms in the District of Columbia, ~~$880,000,000,~~*$898,870,000*, to remain available until September 30, ~~2017~~ *2018.*
(Science Appropriations Act, 2016.)

Education and Human Resources
FY 2017 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Unobligated Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Transfers	Obligations/ Estimates
FY 2015 Appropriation	$866.00	$16.37	-$2.63	$6.59	-	$886.33
FY 2016 Estimate	880.00	2.63				882.63
FY 2017 Discretionary	*898.87*					
FY 2017 (new) Mandatory	*53.99*					
FY 2017 Total Request	952.86					952.86
$ Change from FY 2016 Estimate						$70.23
% Change from FY 2016 Estimate						8.0%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Education and Human Resources (EHR)** account, $2.69 million (including $62,144 in reimbursable funds) was carried over into FY 2016.

Excellence Awards in Science and Engineering (EASE)
- Amount: $2.61 million
- Reason: Approximately $2.33 million for the Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) program was carried over into FY 2016. The FY 2014 awardees were not recognized in FY 2015 and have been scheduled to be recognized in FY 2016 along with the FY 2015 awardees.
- Reason: $275,682 for the Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM) was carried over into FY 2016. The FY 2014 and 2015 awardees were not recognized in FY 2015 and are scheduled to be recognized in FY 2016.
- Anticipated Obligation: FY 2016 Quarter 2

The remaining $23,041 are residual funds from various EHR accounts.

EHR 2017 EHR Summary

EHR's proposed investment in FY 2017 employs three themes to respond to changing population demographics and diversity, changing economic conditions, changes in the nature and practices of science and engineering, and changes in the data- and cyberinfrastructure that is transforming society and the nature of research. These guide the design of solicitations and program activities; EHR's investments are coordinated within these core research areas.[1]

- As part of **broadening participation and institutional capacity**, EHR will serve as a central resource for:
  - Co-leading, with the Directorate for Engineering (ENG) and the Office of Integrative Activities (OIA), the implementation of NSF's investment in Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES). EHR

[1] See Strategic re-re-envisioning for the Education and Human Resources Directorate, September 2014 www.nsf.gov/ehr/Pubs/AC_ReEnvisioning_Report_Sept_2014_01.pdf

will help identify promising strategic goals and objectives that are pivotal for improving the participation of traditionally underrepresented groups, promote implementation research to support scaling of effective models, and involve all EHR broadening participation programs as NSF INCLUDES affiliates.
  - An increased focus on STEM education for Native youths primarily within the Tribal Colleges and Universities program.
  - Co-leading, with the Directorate for Computer and Information Science and Engineering (CISE), the agency priority goal "Public Participation in STEM Research" bringing to bear a growing research base about how engagement of non-experts in scientific research is valuable both for developing interest and learning in science and engineering and increasing scientific output.

- As part of **learning and learning environments**, EHR will promote:
  - Research on the science of learning as translated into educational environments for STEM.
  - Studies about specific learning issues in the STEM disciplines.
  - The development and study of models for improving STEM learning environments and their implementation.
  - Research to further the learning of crosscutting and interdisciplinary topics, such as data science and the science of science communication.
  - Improvement of undergraduate learning opportunities to attract and retain STEM majors, via such emphases as research courses and technological innovations.

- As part of **STEM professional workforce development**, EHR will place particular emphasis on specialized professional development and preparation for:
  - The STEM teachers of tomorrow, through the Robert Noyce Teacher Scholarship Program (Noyce).
  - Future cybersecurity experts through the CyberCorps®: Scholarship for Service (SFS) program.
  - NSF involvement in the training component of the National Strategic Computing Initiative.
  - Innovation in STEM graduate education in a variety of disciplines through the NSF Research Traineeship (NRT) program's Innovation in Graduate Education track.

EHR is a co-lead directorate, with the Directorate for Biological Sciences (BIO), in the development and implementation of the NSF strategic framework for graduate education.

EHR's core education research investment guides strategic and impactful STEM education improvement. In addition, EHR will continue to support the development and study of evidence-based and evidence-generating innovations and models for improving STEM learning. Investment in EHR core research (ECR) is key to improving and solving enduring challenges in STEM education in the three thematic areas that guide EHR's work: the improvement of learning and learning environments; successful models of broadening participation; and educating the STEM workforce for tomorrow. Findings are accumulating to inform investment, policy, and practice in several areas of STEM education. For instance, there is a solid evidence base to support shifts in undergraduate STEM teaching to approaches that emphasize active learning.[2] Education research about mentoring and providing research experiences to undergraduate and graduate students shows the value of focusing explicitly on students' professional development.[3] Research indicates that a critical factor in improving teachers' effectiveness is subject-specific professional

[2] Freeman, S. et al. (2014). Active learning increases student performance in science. *Proceedings of the National Academy of Sciences*. 111: 8410-8415.
[3] Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. *The Journal of Negro Education, 76:* 4, 555-581.

development.[4] There is evidence that engagement in authentic STEM research experiences both inside and outside of school can promote interest and persistence in STEM and course-based research can decrease inequities by expanding research opportunities to more learners from underrepresented groups.[5,6] Student pathways to STEM degree completion are complex; improved metrics, indicators, and data collection systems can help institutions better understand their populations of learners and pathways, including curricular and co-curricular components, that support success in obtaining a STEM degree.[7]

The role of NSF within the federal government, through EHR, in supporting such research on STEM education is unique. EHR programs fund crucial foundational, design and development, and implementation research that is available to inform large investments at scale made by other agencies, organizations, and the private sector for promising or effective practices. The EHR research portfolio also supports the increasingly coherent suite of investments NSF-wide in undergraduate and graduate STEM education. That support occurs through strategic linkages with the discipline-specific needs of all NSF directorates and engagement in cross-directorate science and engineering initiatives. In addition, the EHR investments in preK-12 STEM education and informal STEM learning are focused, catalytic contributions that push the frontiers of effective learning and practice in those environments. Such work is foundational as a part of the national STEM education infrastructure.

Overall, there are no significant shifts in EHR's priorities between FY 2016 and FY 2017. Rather, EHR will intensify its engagement in foundational research, broadening participation, and advancing science and engineering through strategic collaborations across the NSF disciplines.

EHR will participate in the cross-Foundation priorities NSF INCLUDES, Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS), and Understanding the Brain (UtB). For INFEWS and UtB, EHR's emphasis is on innovation in the development of a diverse, next-generation workforce with the skills and competencies needed in these emerging areas through the NRT and Centers for Research Excellence in Science and Technology (CREST) programs. STEM and education communities funded in EHR programs will be encouraged to engage in the NSF INCLUDES National Network, and EHR-based capacity for measurement and indicators in broadening participation will be engaged in the development of the NSF INCLUDES Backbone Organization.

EHR's FY 2017 Budget Request reflects a continuing strong commitment to deepening and strengthening the synergies within EHR and between EHR and the other directorates. Recognizing the unique commitment of NSF in the integration of education and the sciences, EHR's funding prioritizes strategic collaborations that address discipline-specific needs in the sciences and engineering and that utilize the significant experience and expertise of the STEM education community to inform and improve the impact of strategic investments. This is reflected in EHR's interest in expanding the NRT program to align with NSF-wide scientific priorities so that the field can be challenged to devise truly cutting-edge innovations in preparing graduate students to be researchers in these evolving areas. It is also evident in our continued leadership in the Improving Undergraduate STEM Education (IUSE) activity, SFS, and discipline-specific

[4] Penuel, W.R., Fishman, B.J., Yamaguchi, R., & Gallagher, L.P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921-958; and
Garet, M.S., Porter, A., Desimone, L., Birman, B., & Yoon, K.S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.
[5] Locks, A.M., & Gregerman, S.R. (2008).Undergraduate research as an institutional retention strategy: The University of Michigan model. In R. Taraban & R.L. Blanton (Eds.) *Creating effective undergraduate research programs in science: The transformation from student to scientist* (pp. 11-32). New York: Teachers College Press; and Laursen, S. et al. (2010). *Undergraduate research in the sciences: Engaging students in real science*. San Francisco, CA: Jossey-Bass.
[6] National Research Council (2015). *Integrating discovery-based research into the undergraduate curriculum*. Washington, DC: National Academies Press.
[7] National Research Council (2016). *Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support students' diverse pathways*. Washington, DC: National Academies Press; and Locks & Gregerman (2008).

partnerships, as well as in our expansion of NSF Innovation Corps for Learning as a means of stimulating wide use of EHR-funded results and tools.

EHR staff continue to provide cross-agency leadership to the Federal Coordination in STEM Education Task Force (FC-STEM) and the associated Interagency Working Groups (IWG) on the implementation of the *Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan* developed by the Committee on STEM Education (CoSTEM). EHR staff will continue to serve in key roles as co-chairs and members of the groups and will provide support in development of the evidence base, with the long-term outcome to be a more impactful and efficient federal investment in STEM education.

FY 2017 Summary by Division

- The Division of Research on Learning in Formal and Informal Settings (DRL) invests in foundational research on STEM learning. This includes the development and testing of innovative resources, models, and tools for STEM learning both inside and outside of school, for the public, for preK-12 students, for teachers, and for youth; research on national STEM education priorities; and evaluation studies and activities. The FY 2017 DRL investment for ECR: STEM Learning supports a wide range of high quality foundational studies across the STEM domains and across levels and institutional type. The Discovery Research PreK-12 (DRK-12) program supports awards that focus on research and development models and tools for preK-12 education. The Advancing Informal STEM Learning (AISL) program allows expanded emphasis on broadening participation through informal learning environments, including out-of-classroom experiences. DRL, in collaboration with CISE, will lead NSF's involvement in the Administration's Computer Science (CS) for All initiative which accelerates NSF's ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation.

- The Division of Graduate Education (DGE) provides support to U.S. graduate students and innovative graduate programs to prepare tomorrow's leaders in STEM. DGE's role includes support for research that focuses on the general issues related to the development of the STEM professional workforce at the graduate level. In FY 2017, through ECR: STEM Professional Workforce Preparation, DGE will increase its interactions with STEM workforce preparation programs based in other EHR divisions in areas such as teacher preparation and professional development and STEM career development at the undergraduate level. DGE provides intellectual leadership for the use and conduct of research that provides the knowledge base that informs implementation of successful approaches, practices, and models for STEM professional workforce preparation. Another focus for DGE in FY 2017 is reflected in the plan to align NRT with the NSF-wide scientific priorities INFEWS and UtB. At the same time, DGE will continue to promote innovation in graduate education through activities that provide new professional development opportunities for the Graduate Research Fellowship program (GRFP) fellows (i.e., Graduate Research Opportunities Worldwide (GROW) and Graduate Research Internships Program (GRIP)) and through research on the implementation of innovative new program and learning opportunities. In addition, DGE will be involved in the pilot activities in graduate education that are underway as part of NSF's Agency Priority Goal on expanding professional development for graduate students. Another key emphasis for DGE is the expansion of the SFS program to increase the quality of the preparation of tomorrow's cybersecurity experts to predict, engage and recover from cyber-attacks through support of more and well-prepared students' entry into this field through scholarships and government access to their expertise over time.

- The Division of Human Resource Development (HRD) invests in building a diverse and well-qualified STEM workforce through broadening the participation of groups underrepresented in STEM. In FY 2017, HRD programs serve as a foundation for NSF INCLUDES, and all will be affiliated with it. In FY 2017, HRD continues leading efforts to improve STEM education for Hispanic students and at

Hispanic-serving Institutions (HSIs) by focusing on Hispanic-serving two-year institutions in partnership with a variety of programs throughout EHR, within a programmatic framework that recognizes the diverse needs of the varied types of HSIs. HRD investments in Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), and other minority-serving institutions (MSIs) remain critically important. These programs together with ADVANCE, CREST, and the Louis Stokes Alliances for Minority Participation (LSAMP) program will be instrumental in encouraging its principal investigator (PI) community to lead the development of a set of specific goals and objectives for inclusion within NSF INCLUDES. HRD also leads the ECR: Broadening Participation and Institutional Capacity in STEM activity which builds the research base for the science of broadening participation.

- The Division of Undergraduate Education (DUE) provides NSF-wide leadership and expertise for transforming undergraduate STEM education to meet the needs of the 21st century STEM workforce. DUE will continue to emphasize evidence-based and evidence-generating approaches to improve undergraduate education; discipline-focused needs in learning research and development of physical and virtual tools, technologies, and other learning experiences; and emerging areas of science in undergraduate programs in STEM. DUE is the lead division for the NSF-wide IUSE activity which serves as an umbrella for agency-wide investments in undergraduate STEM education. EHR's contribution to IUSE allows for expanded focus on research experiences as part of the undergraduate STEM experience. In FY 2017, DUE's IUSE: EHR program will partner with other directorates on discipline-specific needs in undergraduate education. Funding for ECR: STEM Learning Environments will increase to support fundamental research in STEM education. Further, DUE will continue to focus on supporting the Administration's goal of generating 100,000 new effective STEM teachers and one million more STEM graduates through the Noyce program-in conjunction with HRD's Excellence Awards in Science and Engineering (EASE) program.

Major Investments

EHR Major Investments
(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate: Amount	Change Over FY 2016 Estimate: Percent
CIF21	$2.50	$2.50	$2.50	-	-
GRFP	166.52	165.96	166.08	0.12	0.1%
NSF I-Corps™	0.55	1.55	1.55	-	-
NSF INCLUDES	-	3.00	4.00	1.00	33.3%
INFEWS	-	4.00	6.00	2.00	50.0%
Improving Undergraduate STEM Education (IUSE)	83.84	87.00	92.50	5.50	6.3%
NSF Research Traineeship (NRT)[1]	40.74	31.05	37.71	6.66	21.4%
SaTC	45.04	50.00	70.00	20.00	40.0%
Understanding the Brain	5.00	11.00	11.00	-	-
BRAIN	*2.00*	*2.00*	*2.00*	-	-

Major investments may have funding overlap and thus should not be summed.

[1] FY 2015 funding for Integrative Graduate Education and Research Traineeship (IGERT) ($4.60 million) is included in the NRT line.

- Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21): In FY 2017, through the Project and Program Evaluation (PPE) program, $2.50 million will support

CIF21's Building Community and Capacity for Data-intensive Research activity. For more information, see the CIF21 narrative within the NSF-Wide Investments chapter.

- Graduate Research Fellowship Program (GRFP): GRFP increases $120,000, to a total of $166.08 million. An equal investment is provided through the Integrative Activities budget for a total GRFP investment of $332.16 million. For more information, see the Major Investments in STEM Graduate Education narrative within the NSF-Wide Investments chapter.

- NSF Innovation Corps (I-Corps™): In FY 2017, DUE will support EHR's participation in this activity at a level of $1.55 million. For more information, see the I-Corps™ narrative within the NSF-Wide Investments chapter.

- NSF INCLUDES: In FY 2017, $4.0 million will support NSF INCLUDES Alliances. For more information, see the NSF INCLUDES narrative within the NSF-Wide Investments chapter.

- Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS): $6.0 million will support emphasis on the food-energy-water nexus research area through NRT. For more information, see the INFEWS narrative within the NSF-Wide Investments chapter.

- Improving Undergraduate STEM Learning (IUSE): In FY 2017, EHR will lead the NSF-wide IUSE activity with an investment of $92.50 million and coordinate the participation of the Directorates for Geosciences (GEO), BIO, and ENG. Research and Related Activities (R&RA) account funding will be retained within individual directorates and offices and totals $16.50 million for a Foundation IUSE investment of $109.0 million. For more information, see the IUSE narrative within the NSF-Wide Investments chapter.

- NSF Research Traineeship (NRT): The investment for FY 2017 NRT activities is $37.71 million, of which $7.0 million is dedicated to supporting Innovation in Graduate Education (IGE) for model design, innovation, and research in graduate student training and professional development. For more information, see the Major Investments in STEM Graduate Education narrative within the NSF-Wide Investments chapter.

- Secure and Trustworthy Cyberspace (SaTC): Through the CyberCorps®: Scholarship for Service (SFS) program, EHR will support SaTC activities at $70.0 million. Additional SFS funding in FY 2017 will lay the groundwork for SFS alumni to be available over the course of their careers to serve the federal government to help respond rapidly to cybersecurity challenges.

- Understanding the Brain (UtB): Through the NRT, EHR core research (ECR), IUSE, and DRK-12 programs, EHR will invest in cognitive and learning sciences research efforts at the level of $11.0 million to better understand brain function during learning and problem solving in specific domains of STEM education, and to translate and apply findings from neuroscience and cognition for the improvement of education. EHR investments also will support the preparation of the next generation of neuroscientists and cognitive scientists. This investment includes $2.0 million for the Administration's Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative.

Summary and Funding Profile

EHR supports investment in core research in education and STEM learning as well as STEM education development and training. In FY 2017, the number of research grant proposals is estimated at 3,200. EHR expects to award approximately 570 research grants with an average annualized award size and duration of $290,000 and 2.8 years, respectively.

EHR Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,243	4,250	4,650
Number of New Awards	831	845	930
Funding Rate	20%	20%	20%
Statistics for Research Grants:			
Number of Research Grant Proposals	2,873	2,900	3,200
Number of Research Grants	515	525	568
Funding Rate	18%	18%	18%
Median Annualized Award Size	$167,391	$170,000	$170,000
Average Annualized Award Size	$289,493	$290,000	$290,000
Average Award Duration, in years	2.7	2.8	2.8

Program Monitoring and Evaluation

EHR continues its strong emphasis on evidence-based decision making, through projects, programs, and investment portfolios that are evidence-based, evidence building, and evidence improving. In fiscal years 2016 and 2017, EHR will further consolidate program-based monitoring systems, initiate use of administrative data and on-going data collections for monitoring and evaluation, and fully integrate monitoring and evaluation investments. This work aligns closely with the CoSTEM 5-Year Strategic Plan Objective 2: Build and use evidence-based approaches.[8] Using the joint NSF and Institute of Education Sciences (IES) report, *Common Guidelines for Education Research and Development*, released in FY 2013, EHR will ensure that promising practices, key findings, and accumulated knowledge in evaluation are used and adapted for use internally and disseminated to the larger evaluation community. Plans are underway for updating that report in FY 2017.

The National Research Council (NRC) report *Monitoring Progress Toward Successful K-12 STEM Education* (2013) laid the groundwork for a significant effort launched in FY 2014 to develop indicators for tracking progress in preK-12 STEM education, an essential component in developing evidence-based programs. EHR and the National Center for Science and Engineering Statistics, in collaboration with the National Center for Education Statistics (NCES) within IES, are coordinating efforts to adapt and implement data collection on these indicators within other national efforts.

EHR-based infrastructure and processes will be developed in collaboration with the NSF Evaluation and Assessment Capability, as appropriate. EHR experts in evaluation will provide expertise as needed within NSF and to other federal agencies engaged in STEM education program evaluation as a means of sharing best practices, developing tools for portfolio and data analysis, working toward the use of common metrics and instruments, and building collaborative expertise for STEM education evaluation across agencies.

[8] www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

External Evaluations and Committee of Visitors (COV) completed in FY 2015 and FY 2016:

- COVs for the GK-12/IGERT/SFS, Noyce/Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM), and Advanced Technological Education (ATE) programs, as well as a COV for DRL, were held in 2015.
- The Informal Science Education (ISE) program evaluation conducted by SRI International was completed in FY 2015. The ISE program is now known as the Advancing Informal Science Learning (AISL) program.
- The Innovative Technology Experiences for Students and Teachers (ITEST) program evaluation conducted by SRI International was completed in FY 2015.
- The National STEM Digital Library/Distributed Learning (NSDL) program evaluation conducted by Guardians of Honor was completed in FY 2015.
- The Research and Evaluation on Education in Science and Engineering (REESE) program evaluation conducted by Westat was completed in FY 2015.
- The Discovery Research PreK-12 (DRK-12) program evaluation conducted by Westat was completed in FY 2016.

COVs tentatively scheduled for FY 2016 and FY 2017:

- EHR plans to hold a COV in spring 2016 to review the first three years of the ECR program, which spans all four divisions in the directorate.
- DUE plans to hold a COV in fall 2016 to review the final two years of the Transforming Undergraduate Education in STEM (TUES) program, STEM Talent Expansion Program (STEP), and the Widening Implementation and Demonstration of Evidence-Based Reforms (WIDER) program, along with the first year of the IUSE: EHR program, which consolidated TUES, STEP, and WIDER.
- HRD plans to hold a division-wide COV in fall 2016 to review all HRD programs—i.e., ADVANCE, Alliances for Graduate Education and the Professoriate (AGEP), CREST, Historically Black Colleges and Universities–Undergraduate Program (HBCU-UP), LSAMP, and the Tribal Colleges and Universities Program (TCUP).
- DGE plans to hold a division-wide COV in FY 2017 to review DGE professional workforce programs—i.e., NRT, SFS, and GRFP.

For details regarding the periodic reviews of programs and portfolios of programs by external COVs and directorate advisory committees, please see the Performance chapter for additional information.

Number of People Involved in EHR Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	5,784	5,700	6,300
Other Professionals	2,478	2,400	2,600
Postdoctoral Associates	288	200	300
Graduate Students	10,873	10,800	11,800
Undergraduate Students	15,262	15,200	16,500
K-12 Teachers	36,010	35,800	39,000
K-12 Students	76,000	75,000	82,300
Total Number of People	146,695	145,100	158,800

DIVISION OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS (DRL) $249,280,000 +$26,530,000 / 11.9%

DRL Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, DRL	**$227.20**	**$222.75**	**$249.28**	**$26.53**	**11.9%**
Learning and Learning Environments	**25.94**	**25.63**	**52.16**	**26.53**	**103.5%**
EHR Core Research (ECR): STEM Learning	25.94	25.63	52.16	26.53	103.5%
Broadening Participation & Institutional Capacity	**139.07**	**145.24**	**145.24**	**-**	**-**
Advancing Informal STEM Learning (AISL)	55.01	62.50	62.50	-	-
Discovery Research PreK-12 (DRK-12)	84.06	82.74	82.74	-	-
STEM Professional Workforce	**62.19**	**51.88**	**51.88**	**-**	**-**
INSPIRE	0.22	-	-	-	N/A
Science, Technology, Engineering, Mathematics + Computing (STEM + C) Partnerships	61.97	51.88	51.88	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for the Division of Research on Learning in Formal and Informal Settings (DRL) is $249.28 million, of which $201.84 million is discretionary funding and $47.44 million is new mandatory funding. The mandatory funding is within the following funding lines in the above table: EHR core research ($9.30 million, to a total of $52.16 million); AISL ($7.50 million, to a total of $62.50 million), and STEM + Computing (STEM + C) Partnerships ($30.64 million, to a total of $51.88 million).

DRL invests in foundational research to advance understanding about STEM learning and teaching. The DRL portfolio also includes the design, implementation, and study of learning environments, models, and technologies intended to engage and enable STEM learning for all students, particularly those who have been underrepresented in STEM, through both formal and informal STEM activities both within formal education systems and beyond. DRL also provides direction for the EHR portfolio in techniques for measurement and assessment of learning outcomes. The results of DRL-funded projects are a resource for establishing renewed and new partnerships with other directorates, NSF-funded facilities, other agencies, and the private sector for complementary investments in discipline- and practice-based approaches to STEM education.

DRL provides leadership for: 1) EHR’s core research portfolio; 2) cyberlearning and big data investments, 3) the NSF-wide Einstein Fellows program; 4) agency-wide participation in public participation in scientific research investments, in partnership with CISE, through the Agency Priority Goal; and 5) research collaborations with other directorates related to big data and data science; neuroscience; the science of learning; smart and connected communities; and promoting research to advance the participation of women and girls in STEM, in part by addressing biases against girls, women, and underrepresented minority groups in STEM learning environments (in partnership with the EHR/Human Resource Development division); and catalyzing research for increasing the participation of people with disabilities and learning challenges in STEM.

In FY 2017, DRL will invest across its programs in research and development at the early childhood level intended to foster STEM learning. DRL will support research employing data science methodologies to significantly advance the field's knowledge base on STEM learning and learning environments; broadening participation and institutional capacity in STEM; and increasing retention for students traditionally underserved in STEM at the preK-12, undergraduate, and/or graduate level. DRL will fund research and development related to understanding, measuring, and enhancing socioemotional skills such as persistence, teamwork, and learning to learn, in light of evidence indicating these skills are important for positive STEM educational outcomes. DRL programs will seek proposals for research and development that are driven by questions and needs of practitioners, the diverse nature of K-12 schools including shifting demographic contexts and students with learning disabilities, and the importance of conducting research in settings that include significant numbers of students of low socio-economic status. Finally, in FY 2017, DRL will increase efforts to engage the STEM education research and development communities with technology improvements, shared data, networked research activity, and implementation and improvement research.

In FY 2017, through the Innovative Technology Experiences for Students and Teachers (ITEST) program, DRL will lead EHR's involvement in the Administration's CS for All initiative, by making $10.0 million available to advance the effective teaching and learning of computer science in K-12 education. In addition, DRL will contribute $5.0 million to NSF's UtB initiative; this includes $2.0 million for the Administration's Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative to support research on the neural and cognitive basis of STEM learning.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Learning and Learning Environments

- ECR: STEM Learning increases $26.53 million, to a total of $52.16 million. This program will continue to expand and deepen the portfolio of foundational STEM education research on learning, learning environments, broadening participation, and the STEM professional workforce. An area of emphasis within the learning and learning environments theme for FYs 2016 and 2017 will be early childhood STEM learning, which will be highlighted in ECR along with the Research in Disabilities Education and Research on Gender in Science and Engineering emphases. Increased funding will enable more strategic and coordinated research investment in areas of high importance for improving STEM learning across all of the Nation's demographics, including new knowledge about how to successfully develop talent in groups that have traditionally been underrepresented in STEM. DRL will also provide new direction for partnerships with science-rich entities funded across the NSF, such as large facilities, and centers, in order to explore the potential of these learning environments for engaging and exciting STEM learners of all ages, and for enhancing data infrastructure to advance STEM education research.

Broadening Participation and Institutional Capacity in STEM

- Broadening participation investments in FY 2017 will continue to focus on understanding changing demographics and building talent so that diversity is an asset for science. AISL remains at the FY 2016 Estimate level of $62.50 million. These resources will support design, adaptation, implementation, and research on innovative modes of learning in the informal environment, including emphases on public participation in scientific research, making, and cyberlearning. AISL will continue to encourage projects that utilize informal learning environments in novel ways to engage students from groups traditionally underrepresented in STEM and will continue with Phase 2 of the Wellcome Trust Science Learning+ collaboration, a partnership grant program supporting joint U.S. and United Kingdom initiatives.

- DRK-12 investments will remain at the FY 2016 Estimate level of $82.74 million. These funds are aimed at improving STEM achievement for all preK-12 students. Investments will focus on enabling success for preK-12 students in all groups and across diverse educational settings, and STEM discipline-specific, and interdisciplinary, teaching and learning challenges. STEM teachers, developers, and researchers must keep pace with and contribute to deeper understandings about the technologies that inform their work; build, study, adapt, and implement evidence-based instructional materials and assessment models; translate and use lessons emerging from the science of learning; and become expert in how best to prepare the Nation's diverse learners for the future. The teacher education emphasis in DRK-12 continues its focus on implementation research on policy and practice issues associated with national and state activities, and on the role of authentic STEM research experiences in teacher development and in learning environment design as a means of reaching a wide range of students.

STEM Professional Workforce

- The STEM + C Partnerships program advances research on and development of innovative courses, curriculum, course materials, pedagogies, instructional strategies, and models that integrate computing into one or more other STEM disciplines. In addition, the program builds capacity in K-12 computing education with foundational research and focused teacher preparation. The program advances a 21st century vision for STEM education in which computing is integral to all STEM disciplines and essential to STEM learning and teaching. The STEM + C Partnerships program will be an important resource for the evolving CS for All initiative. EHR's FY 2017 STEM + C Partnerships investment is $51.88 million.

DIVISION OF GRADUATE EDUCATION (DGE) $305,260,000

+$26,780,000 / 9.6%

DGE Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, DGE	**$286.14**	**$278.48**	**$305.26**	**$26.78**	**9.6%**
Learning and Learning Environments	**15.79**	**15.50**	**15.50**	**-**	**-**
Project and Program Evaluation (PPE)	15.79	15.50	15.50	-	-
STEM Professional Workforce	**270.35**	**262.98**	**289.76**	**26.78**	**10.2%**
EHR Core Research (ECR): STEM Profesional Workforce Preparation	16.10	15.97	15.97	-	-
CyberCorps®: Scholarship for Service (SFS)	45.04	50.00	70.00	20.00	40.0%
Graduate Research Fellowship (GRF)	166.52	165.96	166.08	0.12	0.1%
INSPIRE	1.75	-	-	-	N/A
NSF Innovation Corps (I-Corps™)	0.20	-	-	-	N/A
NSF Research Traineeship (NRT)[1]	40.74	31.05	37.71	6.66	21.4%

Totals may not add due to rounding.

[1] FY 2015 funding for Integrative Graduate Education and Research Traineeship (IGERT) ($4.60 million) is included in the NRT line.

The FY 2017 Budget Request for the Division of Graduate Education (DGE) is $305.26 million in discretionary funding.

DGE provides leadership across NSF for investments that support U.S. graduate students in science and engineering and for improvement and innovation in graduate education to prepare tomorrow's leaders for numerous new and existing roles in STEM. DGE focuses on the development of the broad STEM professional workforce through excellent graduate education.

In FY 2017, DGE will further emphasize research on the development of the STEM workforce through ECR. In FY 2017, the SFS program will use $25.0 million to expand its collaborations with other federal agencies to explore mechanisms through which this well-prepared workforce can continue to contribute to government throughout their careers. In addition, through the SFS program, DGE will initiate activities to strengthen and expand university capacity to prepare and provide continuing education for diverse cadres of cybersecurity experts for the Nation who are ready to identify evolving cyber threats. The program also will support research and development in programs, curriculum, and assessment related to cybersecurity educational needs at every level of higher education. Finally, efforts to engage community colleges in the preparation of cybersecurity professionals will continue. See the Major Investments in STEM Graduate Education section in the NSF-wide Investments chapter for more information.

Another focus for DGE is the continued inclusion of INFEWS and UtB as priority research areas in the NRT program in FY 2017. At the same time, DGE will continue to promote innovation in graduate education from activities that range from new research and professional development opportunities for all graduate students supported by fellowships, scholarships, and traineeships (modeled on Graduate Research Opportunities Worldwide (GROW) and Graduate Research Internship Program (GRIP)) to research on the implementation of innovative new program and learning opportunities such as those in NRT and NRT's Innovation Graduate Education track. DGE will increase its emphasis on broadening participation in the STEM workforce through additional outreach to HSIs, HBCUs and TCUs as well as providing additional opportunities for veterans. DGE will support UtB at a level of $4.0 million through the NRT and ECR: STEM Professional Workforce Preparation programs. Partnerships and new pilot activities with disciplinary divisions across NSF are being developed in FY 2016 through the Agency Priority Goal on designing graduate education to better prepare tomorrow's STEM workforce. DGE is collaborating in these efforts to meet the needs of graduate education within specific fields, and expand promising approaches.

With BIO, DGE has administrative and intellectual responsibility for the development and implementation of the NSF strategic plan in graduate education. DGE also leads the EHR evaluation portfolio (particularly in the area of human capital), and is co-lead with NIH in the FC-STEM IWG on Graduate Education.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Learning and Learning Environments

- The request for PPE is $15.50 million, equal to the FY 2016 Estimate. Administrative oversight for EHR's activity in evaluation, monitoring, and related research activities will reside in DGE, and staff will collaborate closely with the Evaluation and Assessment Capability in OIA. Efforts will include launching long-term studies to examine and compare the impact of various NSF investment approaches in graduate students and funding the development of instruments to assess metrics identified in the NRC report, *Monitoring Progress Toward Successful K-12 STEM Education* (2013). The Promoting Research and Innovative Methodologies for Evaluation (PRIME) activity within the PPE program is on hold in FY 2016 for review. In FY 2017, it is anticipated that resources will be realigned to take up examination of other issues, including methodology for studying graduate education, data privacy in research and evaluation, and use of administrative data in evaluation.

STEM Professional Workforce

- ECR: STEM Professional Workforce Preparation ($15.97 million) investments will expand the knowledge base to improve STEM professional workforce development at all educational levels through development of models, research, and evaluation, and will allow translation of the results of the research for adoption/adaptation in workforce and education programs.
- SFS increases $20.0 million, to a total of $70.0 million. In FY 2017, NSF will invest $25.0 million in the expansion of the SFS program to lay the groundwork for SFS program alumni to be available over the course of their careers to serve the federal government's response to cybersecurity challenges. SFS funding will improve the capacity of institutions to provide the latest curricular and assessment approaches and experiences available to ensure that the students are well prepared with cybersecurity skills and knowledge, and to conduct research to build understanding of the most effective preparation for a variety of cybersecurity professions. It also will enable awards to a broader spectrum of institutions to make additional scholarships. Due to greater capacity, increased attention will be directed to community colleges, continuing an effort launched in FY 2015.
- EHR's portion of GRFP increases $120,000, to a total of $166.08 million. The program will support 2,000 new fellowships with a cost of education allowance of $12,000 and a stipend of $34,000. For more information, see the Major Investments in STEM Graduate Education narrative within the NSF-Wide Investments chapter.
- In FY 2017, EHR's NRT investment increases $6.66 million, to a total of $37.71 million. NRT will continue to support projects in the FY 2017 NSF-wide priorities INFEWS and UtB. As part of the Innovation in Graduate Education track, NRT will challenge the field to devise, implement, and assess cutting-edge innovations in preparing graduate students to be researchers in these evolving areas. NRT will seek bold new STEM graduate education pilots and models in order to transform current practices in graduate education.

DIVISION OF HUMAN RESOURCE DEVELOPMENT (HRD) $155,890,000
+$5,660,000 / 3.8%

HRD Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, HRD	**$143.90**	**$150.23**	**$155.89**	**$5.66**	**3.8%**
Learning and Learning Environments	**55.14**	**58.53**	**58.53**	**-**	**-**
ADVANCE	1.52	1.53	1.53	-	-
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	8.00	8.00	-	-
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	32.04	35.00	35.00	-	-
Tribal Colleges and Universities Program (TCUP)	13.58	14.00	14.00	-	-
Broadening Participation & Institutional Capacity	**58.83**	**61.88**	**67.54**	**5.66**	**9.1%**
EHR Core Research (ECR): Broadening Participation and Institutional Capacity in STEM	12.92	12.88	17.54	4.66	36.2%
NSF INCLUDES	-	3.00	4.00	1.00	33.3%
Louis Stokes Alliances for Minority Participation (LSAMP)	45.91	46.00	46.00	-	-
STEM Professional Workforce	**29.93**	**29.82**	**29.82**	**-**	**-**
Centers for Research Excellence in Science and Technology (CREST)	24.01	24.00	24.00	-	-
Excellence Awards in Science and Engineering (EASE)	5.92	5.82	5.82	-	-

Totals may not add due to rounding

The FY 2017 Budget Request for the Division of Human Resource Development (HRD) is $155.89 million, of which $153.09 million is discretionary funding and $2.80 million is new mandatory funding. The mandatory funding is within the EHR core research line in the above table.

HRD provides support to grow the innovative and competitive U.S. STEM workforce by supporting the inclusion and success of individuals currently underrepresented in STEM and the institutions that serve them, and conducting research on effective mechanisms and models for achieving both of these goals.

In FY 2017, EHR will continue its substantial role in NSF-wide activities to strengthen inclusion and broadening participation for all groups in STEM. EHR is a co-lead organization in the implementation of NSF INCLUDES, with primary expertise coming from HRD. HRD anticipates that members of the principal investigator community from all HRD-based programs will be leaders and innovators in the NSF INCLUDES initiative, and all HRD programs will affiliate with NSF INCLUDES. The NSF INCLUDES Network Alliances will be promoted strongly through HRD programs, and the LSAMP program will introduce an NSF INCLUDES Alliance track. The ADVANCE program will pilot a special track, tentatively named Increasing the Participation and Success of Faculty of Color in Academic Science and Engineering Careers (SUCCESS), in connection with NSF INCLUDES. HRD also will continue efforts from FY 2016 to provide publicity and outreach to the rapidly growing set of HSIs to encourage increased proposal submission to the many programmatic opportunities available at EHR to address the specific needs of particular types of HSIs, within a program framework for investment.

HRD will increase its partnerships with other organizations (e.g., the U.S. Department of Education's Office of Postsecondary Education's Hispanic-Serving Institutions Division and U.S. Department of Agriculture's National Institute of Food and Agriculture) to advance Administration STEM education priorities. The AGEP program will focus on the transition from postdoctoral training to faculty position, particularly for those who are underrepresented in STEM. New coordinated efforts will be built among the LSAMP, IUSE, and ATE programs to enhance the persistence of undergraduate students, and with GRFP to reach talent broadly for the Nation and to diversify the GRFP applicant pool. HRD will work with the SFS program, particularly in preparing and supporting students from two-year colleges to transition into four-year degree courses that are supported by SFS. HRD has administrative and intellectual responsibility for EASE, in partnership with the Office of Science and Technology Policy. EASE will continue to support professional development for K-12 teachers and STEM educators and mentors, as well as the identification and recognition of educators who have particular impact on broadening participation. Collaborative efforts among the EASE, Noyce, and DRK-12 programs will support the professional development of preK-12 teachers, and connections will be made from HRD to CS for All to increase the access to computer science for students in groups traditionally underrepresented in STEM. HRD is co-lead with NIH in the FC-STEM Broadening Participation IWG.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Learning and Learning Environments

- HRD supports the development of effective STEM learning and learning environments through several existing programs (ADVANCE, AGEP, HBCU-UP, and TCUP). These programs will continue to build on the knowledge about successful approaches to broadening STEM participation with a focus on retention of underrepresented undergraduate students and building institutional capacity in MSIs.
- In FY 2017, ADVANCE will continue to support work in institutional transformation and faculty development, focus on the advancement of women of color, as well as focus on disciplinary areas that foster collaborations through developing networks and partnerships.
- AGEP will support innovative and sustainable ways to promote inclusion in the STEM academic workforce, and will implement new strategies to work with the NRT program and GRFP focusing on transitions from graduate to postdoctoral training to increase STEM career opportunities. AGEP will look into models that support the transition of postdoctoral scientists to faculty positions.
- TCUP will work with the Howard Hughes Medical Institute, to provide Native American students more hands-on learning experiences in the classroom. HRD programs will support studies on learning issues and challenges in specific STEM disciplines in order to understand better the factors that may increase retention and completion rate of underrepresented students.

Broadening Participation and Institutional Capacity in STEM

- In FY 2017, HRD will continue to provide strategic direction and guidance for the broadening participation and institutional capacity component of ECR. ECR funding increases by $4.66 million in FY 2017 to a total of $17.54 million. HRD will integrate into ECR the broadening participation research tracks of all HRD programs to support more investigators from MSIs that will carry out foundational research to explore topics, such as: approaches to using diversity as an asset for science; successful approaches that engage a diverse group of learners and audiences; the use of culturally relevant materials in engaging learners from groups traditionally underrepresented in STEM; and development and implementation of models that support persistence, retention, and success in STEM for groups underrepresented in STEM disciplines. In addition, MSIs will be encouraged to explore research topics and workshops that support capacity building at these institutions, with a focus on developing faculty to carry out STEM education research.

- HRD's funding for NSF INCLUDES increases by $1.0 million to a total of $4.0 million to support the development of the NSF INCLUDES Alliances and the Backbone Organization. HRD will lead EHR efforts to incorporate the principles of NSF INCLUDES across all programs, as appropriate, and will play a key role in the development of metrics and approaches to the assessment of NSF INCLUDES and other investments in broadening participation.
- LSAMP funding is $46.0 million in FY 2017, equal to the FY 2016 Estimate.

STEM Professional Workforce

- The graduate education component of the CREST program is part of a National Academies of Science (NAS) review on effective practices in STEM graduate education to be initiated in FY 2016. It is expected that based on the NRC review findings, the CREST program will be changed to better address the needs of the field in FY 2017 and FY2018. CREST introduced a Postdoctoral Research Fellowship track in FY2016 which fosters increased collaborations across the centers and builds research capacity at MSIs. CREST funding is $24.0 million in FY 2017, equal to the FY 2016 Estimate.
- EASE will remain at the FY 2016 Estimate level of $5.82 million and will continue to support professional development for K-12 teachers and STEM educators and mentors, as well as the identification and recognition of educators who have particular impact on broadening participation.

DIVISION OF UNDERGRADUATE EDUCATION (DUE) $242,430,000
+$13,890,000 / 6.1%

DUE Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, DUE	**$229.08**	**$228.54**	**$242.43**	**$13.89**	**6.1%**
Learning and Learning Environments	**100.00**	**100.10**	**113.99**	**13.89**	**13.9%**
EHR Core Research (ECR): STEM Learning Environments	16.16	13.10	21.49	8.39	64.0%
Improving Undergraduate STEM Education (IUSE)	83.84	87.00	92.50	5.50	6.3%
STEM Professional Workforce	**129.08**	**128.44**	**128.44**	**-**	**-**
Advanced Technological Education	67.67	66.00	66.00	-	-
NSF Innovation Corps (I-Corps™)	0.35	1.55	1.55	-	-
Robert Noyce Teacher Scholarship Program (Noyce)	61.06	60.89	60.89	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for the Division of Undergraduate Education (DUE) is $242.43 million, of which $238.68 million is discretionary funding and $3.75 million is new mandatory funding. The mandatory funding is within the EHR core research line in the above table.

DUE supports the design, development, and study of innovative STEM learning environments that integrate cutting-edge science and education findings to optimize learning for all undergraduates. DUE invests in discipline-based education research where disciplinary expertise and evidence from the learning sciences are infused into physical and virtual tools, technologies, and other learning experiences, and then iteratively improved through research and development to impact STEM learning at scale.

In FY 2017, DUE programs will continue to provide direction for the nationwide movement to transform undergraduate STEM education by investing in the design, implementation, and study of innovative environments for undergraduate STEM interdisciplinary and disciplinary learning. DUE also continues to be the main source of support across Federal agencies for discipline-based educational research.[9] DUE will focus on investments for improving mathematics learning and teaching, particularly in the first two years; improving data science learning; developing socio-emotional and twenty first century skills in conjunction with STEM learning; and developing the next generation of researchers who will study undergraduate STEM education. In collaboration with the National Center for Education Statistics, plans are being developed for a revision of the National Study of Postsecondary Faculty to provide data on teaching practices, the evolving role of technology in education, and the rapidly changing nature of faculty work, and we anticipate that implementation will begin in FY 2017.

To build a diverse, innovative STEM and STEM-savvy workforce, in FY 2017 a "New-to-IUSE" opportunity will be established in IUSE: EHR for investigators from minority-serving community colleges, as well as investigators from two- and four- year institutions with prior funding from HBCU-UP and TCUP programs and awardees from recent Dear Colleague Letters for HSIs. Across DUE programs, research and

[9] National Research Council (2012) *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Education*, Washington, DC: National Academies Press

development on increasing the success of low income and other underrepresented undergraduate groups in making the transition from two-year to four-year STEM degree programs will be emphasized.

DUE provides administrative leadership for EHR in the NSF-wide IUSE activity, the community college investment portfolio (in partnership with HRD), and in the FC-STEM IWG on Undergraduate Education.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Learning and Learning Environments

- ECR: STEM Learning Environments increases by $8.39 million to a total of $21.49 million. DUE has leadership for this ECR focus area. The increase will support foundational research and related development for the improvement of STEM learning environments, including cyberlearning, as well as the use of data science to understand and improve learning environments. With an investment of $2.0 million, DUE will support UtB.
- DUE's funding for IUSE increases by $5.50 million to a total of $92.50 million. This funding will support scaling evidence-based practices; advancing the knowledge base for undergraduate research, including course-based research; and developing and identifying indicators, metrics, and assessments to measure readiness for and progress toward widespread use of evidence-based resources in undergraduate STEM instruction. DUE will increase the STEM research and experiential learning opportunities available in NSF-funded large facilities, national laboratories, and centers through the S-STEM program in collaboration with the NSF Graduate Research Internship Program (GRIP).
- DUE will work with HRD to align the IUSE: EHR and S-STEM (an H-1B Visa funded program) programs with the LSAMP program to leverage the strengths of all programs for enhancing persistence of students from low-income and underrepresented groups. The two divisions will focus on improving undergraduate learning at HSIs. This alignment will be informed by an HRD- and DUE-funded study by the National Academies on *Barriers and Opportunities in Completing Two or Four Year STEM Degrees.*[10]

  For more information regarding IUSE and NSF's undergraduate framework, see the IUSE narrative in the NSF-Wide Investments chapter.

STEM Professional Workforce

The request for ATE is $66.0 million, equal to the FY 2016 Estimate. Noyce remains at the FY 2016 level of $60.89 million. In FY 2017, ATE activities will continue to fund research on effective preparation of advanced technology technicians; while Noyce will continue investing in teacher preparation. In addition, both programs will continue to have emphasis on the preparation of a diverse STEM workforce and will incorporate a focus on inclusion, in partnership with the NSF INCLUDES initiative.

[10] Board on Science Education. *Barriers and Opportunities in Completing Two or Four Year STEM Degrees.* http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_080405

H-1B NONIMMIGRANT PETITIONER FEES **$100,000,000**

$0 / 0.0%

In FY 2017, H-1B Nonimmigrant Petitioner Fees are projected to be $100.0 million, equal to the FY 2016 estimate.

H-1B Nonimmigrant Petitioner Fees Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate	
				Amount	Percent
H-1B Nonimmigrant Petitioner Fees Funding	$139.17	$100.00	$100.00	-	-

Beginning in FY 1999, Title IV of the American Competitiveness and Workforce Improvement Act of 1998 (P.L. 105-277) established an H-1B Nonimmigrant Petitioner Account in the general fund of the U.S. Treasury for fees collected for each petition for alien nonimmigrant status. That law required that a prescribed percentage of funds in the account be made available to NSF for low-income scholarships; grants for mathematics, engineering, or science enrichment courses; and systemic reform activities. In FY 2005, Public Law 108-447 reauthorized H-1B funding. NSF was provided with 40 percent of the total H-1B receipts collected. Thirty percent of H-1B receipts (75 percent of the receipts that NSF receives) are to be used for a low-income scholarship program, Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM). Ten percent of receipts (25 percent of the receipts that NSF receives) are designated for support of private-public partnerships in K-12 education through Innovative Technology Experiences for Students and Teachers (ITEST).

- **Low-income Scholarship Program: S-STEM.** The S-STEM program provides institutions with funds for student scholarships to encourage and enable academically talented U.S. students demonstrating financial need to enter the STEM workforce or STEM graduate school following completion of an associate, baccalaureate, or graduate degree in fields of science, technology, engineering, or mathematics. The program emphasizes the importance of recruiting students to STEM disciplines, mentoring and supporting students through degree completion, and partnering with employers to facilitate student career placement in the STEM workforce.

  Since its inception, the low-income scholarship program has received over 6,900 proposals from all types of colleges and universities and has made awards for 1,453 projects. In addition to scholarships, projects include a coherent ecosystem of student support activities featuring close involvement of faculty, student mentoring, academic support, curriculum development, and recognition of the students. Such activities are important in recruiting and retaining students in high-technology fields through graduation and into employment. In FY 2017, in addition to the long-standing scholarship support, all S-STEM projects will contribute to the knowledge base of scholarly research in education by carrying out research on interventions which affect associate or baccalaureate degree attainment for academically talented U.S. students demonstrating financial need. Because S-STEM projects report much higher retention and graduation rates among their scholarship students than among other STEM majors, it is important to systematically study the reasons for this success so that effective practices can be used at scale. Approximately 85-90 awards are anticipated in FY 2017, with an emphasis on increasing involvement of community colleges, especially Hispanic-serving institutions. S-STEM activities in FY 2017 will leverage efforts in the IUSE: EHR, LSAMP programs to enhance persistence of students. S-STEM will be a partner in the NSF INCLUDES initiative. S-STEM programming and research emphasis also will align with NRT to understand and enhance development of effective learning environments and pathways for scholarship and traineeship students on the continuum from two-year to four-year to master's to doctoral degrees.

- **Private-Public Partnerships in K-12: ITEST.** The ITEST program invests in K-12 activities that address the ongoing and growing need for STEM professionals and information technology workers in the US and seeks solutions to help ensure the breadth and depth of the U.S. STEM workforce. ITEST funds activities for students and teachers that emphasize mathematics, science, and engineering careers, and emphasizes the importance of evaluation and research to understand the impact of such activities. The program supports the development, implementation, testing, and scale-up of models, STEM robotics projects, and research studies to improve the STEM workforce and build a student's capacity to participate in the STEM workforce. The solicitation places emphasis on capturing and establishing a reliable knowledge base about the dispositions toward and knowledge about STEM workforce skills in U.S. students. Building on FY 2016 investments, ITEST will seek to build its portfolio in the area of computer science, with the intention of infusing more high quality opportunities for the learning of computer science into the Nation's K-12 schools as a part of the Administration's CS for All initiative. In FY 2017, we anticipate aligning $10.0 million within ITEST funding for this initiative.

  Since its inception, the ITEST program has received 4,580 proposals and funded 360 projects that allow students and teachers to work closely with scientists, engineers, and other STEM professionals on extended research projects ranging from biotechnology to environmental resource management to programming and problem-solving. Projects draw on a wide mix of local resources, including universities, industry, museums, science and technology centers, and school districts in order to identify the characteristics that attract a wide and diverse range of young people to STEM careers, especially those students not successful in traditional school settings. ITEST will be a partner in the NSF INCLUDES initiative. Approximately 20 awards are anticipated in FY 2017.

H-1B Financial Activities from FY 2006 - FY 2015
(Dollars in Millions)

	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Receipts	**$105.32**	**$107.36**	**$104.43**	**$88.66**	**$91.22**	**$106.11**	**$128.99**	**$120.94**	**$132.49**	**$143.00**
Unobligated Balance start of year	**$89.58**	**$98.19**	**$63.37**	**$50.83**	**$52.62**	**$50.15**	**$60.93**	**$99.31**	**$104.76**	**$108.35**
Appropriation Previously unavailable (Sequestered)									**$5.10**	**$9.54**
Appropriation Currently unavailable (Sequestered)									**-$9.54**	**-$7.30**
Obligations incurred:										
Scholarships in Science, Technology, Engineering, and Mathematics[1]	80.95	100.04	92.40	61.22	75.96	77.67	72.57	83.98	92.18	109.34
Private-Public Partnership in K-12[2]	18.45	45.90	28.72	27.86	20.85	18.62	21.59	31.51	37.23	29.83
Total Obligations	**$99.40**	**$145.94**	**$121.12**	**$89.08**	**$96.81**	**$96.29**	**$94.16**	**$115.49**	**$129.41**	**$139.17**
Unallocated Recoveries				2.20	3.12	0.96	3.55	-	4.95	1.60
Unobligated Balance end of year	**$95.50**	**$59.61**	**$46.68**	**$52.62**	**$50.15**	**$60.93**	**$99.31**	**$104.76**	**$108.35**	**$116.02**

Totals may not add due to rounding.

[1] In FY 2006, the Computer Science, Engineering, and Mathematics Scholarships (CSEMS) was renamed to Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM).

[2] P.L. 108-447 directs that 10 percent of the H-1B Petitioner funds go toward K-12 activities involving private-publice partnerships in a range of areas such as materials development, student externships, math and science teacher professional development, etc.

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM). The S-STEM program began in 1999 under P.L. 105-277. At this time, the program was named Computer Science, Engineering, and Mathematics Scholarships (CSEMS) and supported grants for scholarships to academically-talented students with demonstrated financial need pursuing associate, baccalaureate, or graduate degrees in computer science, computer technology, engineering, engineering technology, or mathematics. Grantee institutions awarded scholarships of up to $2,500 per year for two years to eligible students. The CSEMS activity continued under the American Competitiveness in the 21st Century Act (P.L. 106-313) with a prescribed percentage of H-1B receipts (22 percent) which totaled approximately 59.5 percent of the total H-1B funding for NSF. P.L. 106-313 also amended P.L. 105-277 by increasing the maximum scholarship duration to four years and the annual stipend to $3,125.

Under the Consolidated Appropriations Act, 2005 (P.L. 108-447), the prescribed percentage of H-1B receipts available for the low income scholarship program was increased to 30 percent (approximately 75 percent of the total H-1B funding for NSF). Eligibility for the scholarships was expanded from the original fields of computer science, engineering, and mathematics to include "other technology and science programs designated by the Director." The maximum annual scholarship award amount was raised from $3,125 to $10,000. Language also was added allowing NSF to use up to 50 percent of funds "for undergraduate programs for curriculum development, professional and workforce development, and to advance technological education." As a result, the program was renamed in 2006 from CSEMS to S-STEM.

Private-Public Partnerships in K-12. The American Competitiveness in the 21st Century Act (P.L. 106-313) amended P.L. 105-277 and changed the way petitioner fees were to be expended. P.L. 106-313 directed the remaining 40.5 percent of the total H-1B funding for NSF (15 percent of H-1B receipts) toward K-12 activities involving private-public partnerships in a range of areas such as materials development, student externships, and mathematics and science teacher professional development. The ITEST program was developed as a partnership activity in K-12 to increase opportunities for students and teachers to learn about, experience, and use information technologies within the context of STEM, including information technology (IT) courses. In FY 2005, P.L. 108-447 reduced the prescribed percentage of H-1B receipts available for private-public partnerships in K-12 to 10 percent (approximately 25 percent of the total H-1B funding for NSF).

Explanation of Carryover

Within the **H-1B Nonimmigrant Petitioner** account, $116.02 million was carried over and consists of $29.96 million for ITEST and $86.06 million for S-STEM. Since NSF receives the largest payments of H-1B visa fees in August and September, there was insufficient time to obligate the receipts on awards before the end of the fiscal year. These resources will allow both ITEST and S-STEM to support awards through the second quarter of FY 2016.

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION — $193,120,000 / -$7,190,000 / -3.6%

Major Research Equipment and Facilities Construction Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Major Research Equipment and Facilities Construction	$144.76	$200.31	$193.12	-$7.19	-3.6%

The Major Research Equipment and Facilities Construction (MREFC) account supports the acquisition, construction, and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Initial planning, design, and post-construction operations and maintenance are funded through the Research and Related Activities (R&RA) account.

MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate
DKIST	$25.12	$20.00	$20.00	$20.00	$16.13	-	-	-
LSST	79.64	99.67	67.12	55.80	47.89	45.75	39.90	9.73
NEON[1]	40.00	80.64	-	-	-	-	-	-
RCRV	-	-	106.00	105.00	44.50	-	-	-
Total	**$144.76**	**$200.31**	**$193.12**	**$180.80**	**$108.52**	**$45.75**	**$39.90**	**$9.73**

Totals may not add due to rounding.

[1] Of the $96.0 million appropriated for NEON in FY 2015, $56.0 million was carried over to FY 2016 and is excluded in the amounts above.

Modern and effective research infrastructure is critical to maintaining U.S. leadership in science and engineering. The future success of entire fields of research depends upon access to new generations of powerful research tools. Increasingly, these tools are large and complex and have a significant information technology or cyber-infrastructure component.

To be considered for MREFC funding, NSF requires that a project represent an exceptional opportunity to enable research and education. The project should be transformative in nature, with the potential to shift the paradigm in scientific understanding. The projects included in this budget request meet these criteria based on NSF and National Science Board review and approval.

In FY 2017, NSF requests $193.12 million to begin construction of one new project, the Regional Class Research Vessels (RCRV), and to continue construction of two projects, the Daniel K. Inouye Solar Telescope (DKIST) and the Large Synoptic Survey Telescope (LSST). Although the construction schedule is going to extend due to management challenges, FY 2016 currently represents the last MREFC funding request for the National Ecological Observatory Network (NEON) as previously planned. For more information on these projects, see the individual narratives later in this chapter.

Since FY 2009, projects funded through the MREFC account have been subject to NSF's "no cost overrun" policy. As a result, NSF processes and procedures must assure the development of realistic and well-supported total project cost estimates for major research facilities such that approved budgets are sufficient to accomplish the scientific objectives.

The current policy requires that (1) the total project cost estimate when exiting the preliminary design phase includes adequate contingency to cover foreseeable risks, and (2) any cost increases not covered by contingency be accommodated first by reductions in scope, provided that the actual enacted funding levels have been consistent with the established annual cash flow requirements. NSF procedures are also designed to assure that tracking contingency use is robust and that program and recipients have sufficient oversight and management authority (respectively) to meet project objectives. NSF is continually improving its internal processes and procedures on oversight, including the requirement for independent cost estimate reviews (per GAO Cost Estimating Guide) and incurred cost audits for MREFC projects. Further, all projects funded through the MREFC account undergo periodic cost, schedule, and risk reviews as required by NSF's Large Facilities Manual, as well as the terms and conditions of the cooperative agreements.

Appropriations Language

For necessary expenses for the acquisition, construction, commissioning, and upgrading of major research equipment, facilities, and other such capital assets pursuant to the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), including authorized travel, ~~$200,310,000~~,*$193,120,000,* to remain available until expended. *(Science Appropriations Act, 2016.)*

Major Research Equipment and Facilities Construction
FY 2017 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Unobligated Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Transfers	Obligations Actual/ Estimates
FY 2015 Appropriation	$200.76	$0.39	-$58.06	$1.67	-	$144.76
FY 2016 Estimate	200.31	58.06			-	258.37
FY 2017 Request	193.12					193.12
$ Change from FY 2016 Estimate						-$65.25
% Change from FY 2016 Estimate						-25.3%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Major Research Equipment and Facilities Construction** no-year account, $58.06 million was carried over into FY 2016. This total is composed of:

- National Ecological Observatory Network (NEON): $56.0 million
  - Reason: FY 2015 obligations were limited in connection with the construction management transition. For additional information, please see the NEON section of this chapter.
  - Anticipated Obligation: FY 2016 Quarter 3

- The remaining $2.06 million is due to a settlement of $1.67 million for the Large Hadron Collider project and $390,691 in residual funds from the Advanced Laser Interferometer Gravitational Wave Observatory project.

The MREFC Account in FY 2017

The following pages present detailed information on NSF's ongoing projects in FY 2017, with sponsoring organization noted in parenthesis. These are:

DANIEL K. INOUYE SOLAR TELESCOPE $20,000,000

The FY 2017 Budget Request for the Daniel K. Inouye Solar Telescope (DKIST) is $20.0 million. This represents the ninth year in an eleven-year funding profile, with an estimated total project cost of $344.13 million. Completion of construction atop Haleakala on Maui, Hawaii is planned for late FY 2019.

When completed in 2019, DKIST will be the world's most powerful solar observatory, poised to answer fundamental questions in solar physics by providing transformative improvements over current ground-based facilities. DKIST will enable the study of magnetic phenomena in the solar photosphere, chromosphere, and corona. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and coronal mass ejections. Solar activity can affect civil life on Earth through phenomena generally described as "space weather" and may have impact on the terrestrial climate. The relevance of DKIST's science drivers was reaffirmed by the National Academy of Sciences 2010 Astronomy and Astrophysics Decadal Survey: *New Worlds, New Horizons*[1] as well as the 2012 Solar and Space Physics Decadal Survey: *A Science for a Technological Society*.[2] DKIST will play an important role in enhancing the "fundamental understanding of space weather and its drivers," an objective called out in the National Space Weather Strategy and associated National Space Weather Action Plan, both of which were released by the National Science and Technology Council on October 29, 2015.

Appropriated and Requested MREFC Funds for the Daniel K. Inouye Solar Telescope
(Dollars in Millions)

	Prior Years	FY 2013 Actual	FY 2014 Actual	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	Total Project Cost
MREFC Approp.	$35.00	$25.00	$36.88	$25.12	$20.00	$20.00	$20.00	$16.13	$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	-	146.00
Total, DKIST	**$181.00**	**$25.00**	**$36.88**	**$25.12**	**$20.00**	**$20.00**	**$20.00**	**$16.13**	**$344.13**

Totals may not add due to rounding.

Baseline History

Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year design and development program for DKIST and its initial complement of instruments through the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and the Division of Atmospheric and Geospace Sciences (AGS) in the Directorate for Geosciences (GEO). The current design, cost, schedule, and risk were scrutinized in an NSF-conducted Preliminary Design Review in October-November 2006.

The original total project cost to NSF, $297.93 million, was set after a Final Design Review (FDR) in May 2009 determined the project was fully prepared to begin construction. The National Science Board (NSB) approved an award for this amount at the NSF Director's discretion, contingent upon completion of compliance with relevant environmental and cultural/historic statutes. In FY 2009, $153.0 million was provided through the Major Research Equipment and Facilities Construction (MREFC) account to initiate construction. Of these MREFC funds, $146.0 million was appropriated through the American Recovery and Reinvestment Act (ARRA). Given the timing of the receipt of budget authority and the complexity of project contracting, the entire $153.0 million was carried over from FY 2009 and obligated in FY 2010.
The environmental compliance requirements were completed on November 20, 2009, and the Record of

[1]www.nap.edu/catalog.php?record_id=12951
[2]www.nap.edu/search/?term=13060&x=0&y=0

Decision authorizing the construction was signed by the NSF Director on December 3, 2009. The Hawaii Board on Land and Natural Resources (BLNR) approved the project's application for a Conservation District Use Permit (CDUP) on December 1, 2010. A Habitat Conservation Plan, designed to protect and rehabilitate habitats of the endangered Hawaiian petrel and Hawaiian goose that could potentially be affected by the construction of DKIST, was approved by the Hawaii BLNR. Formal consultation with the U.S. Fish and Wildlife Service with regard to the endangered Hawaiian petrel was completed in calendar year 2011. Site construction was halted while a Contested Case challenge to the 2010 CDUP issuance was resolved. The BLNR ruled in favor of the DKIST project and a new CDUP was issued in November 2012. Full access to the site atop Haleakala followed shortly thereafter. Site preparation and excavation began November 30, 2012.

The unexpected length of the delay associated with the environmental compliance process led to a reassessment of the project schedule and total project cost in 2012. The revised baseline and an increase in the total project cost of approximately $46.20 million was reviewed by an external panel of experts and subsequently considered by the NSB, which approved a revised total project cost of $344.13 million at their August 2013 meeting.

Total Obligations for DKIST

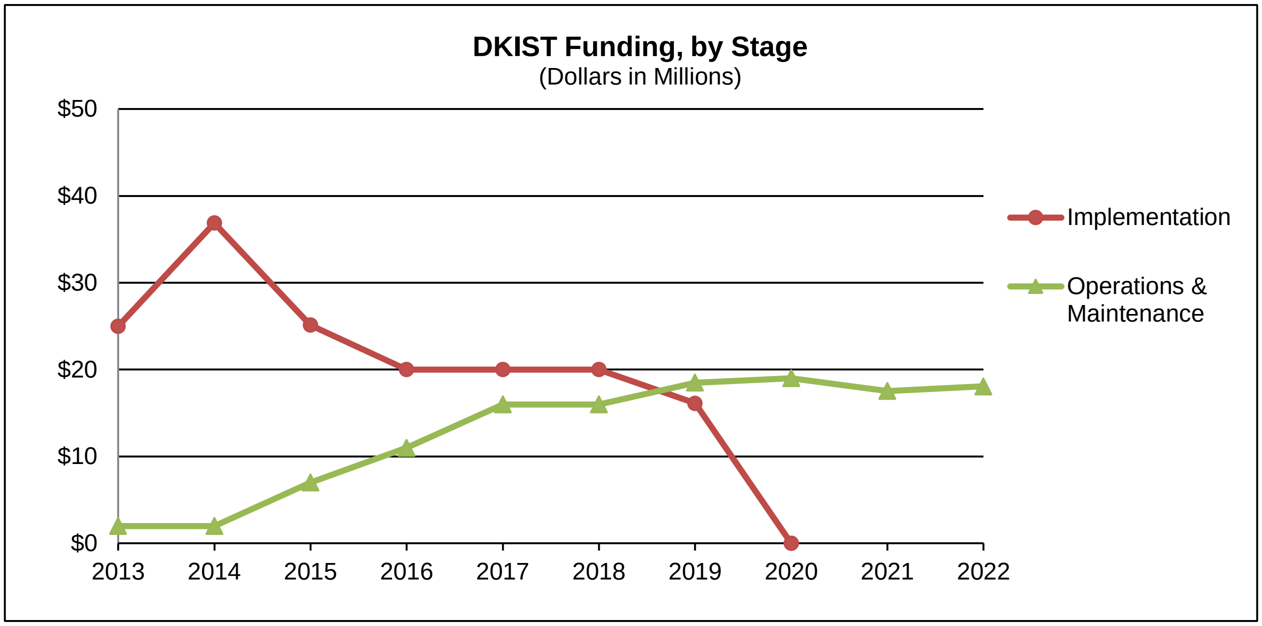
(Dollars in Millions)

					ESTIMATES				
	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	2.00	7.00	11.00	16.00	16.00	18.50	19.01	17.54	18.08
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$25.51	$7.00	$11.00	$16.00	$16.00	$18.50	$19.01	$17.54	$18.08
MREFC Obligations:									
Implementation	96.88	25.12	20.00	20.00	20.00	16.13	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC Obligations	$242.88	$25.12	$20.00	$20.00	$20.00	$16.13	-	-	-
TOTAL Obligations	**$268.39**	**$32.12**	**$31.00**	**$36.00**	**$36.00**	**$34.63**	**$19.01**	**$17.54**	**$18.08**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.

[2] Of the total Operations & Maintenance funding, $2.0 milllion per year for FY 2011 through FY 2020 is for cultural mitigation activities as agreed to during the compliance process. Also included for FY 2017 is $2.50 million for the DKIST Remote Operations Building (should this option be selected); see the NSO narrative in the Facilities chapter for more information.



The DKIST project is a collaboration of scientists and engineers at more than 20 U.S. and international organizations. Other partners include the Air Force Office of Scientific Research and international groups in Germany, the United Kingdom, and Italy. Some of the activities to be performed through these partnerships include:

- The U.S. Air Force replaced the aluminizing chamber at their Advanced Electro-Optical System telescope on Maui and sized it to accommodate the DKIST primary mirror. This obviates the need to build a new aluminizing chamber for DKIST.
- Kiepenheuer-Institut für Sonnenphysik (KIS; Freiburg, Germany) is constructing a narrow-band first-light instrument named the Visible Tunable Filter (VTF).
- Queens University Belfast (Belfast, Northern Ireland) is leading a consortium of institutions from the United Kingdom that will supply high-speed visible cameras to feed the DKIST instruments.

Discussions of other possible contributions for second-generation instruments, algorithm development, coordinated observations, and student exchange are ongoing.

<u>Management and Oversight</u>

- NSF Structure: Oversight from NSF is handled by a program officer in AST working cooperatively with staff from MPS, the Office of Budget, Finance, and Award Management (BFA), and the Offices of General Counsel and Legislative and Public Affairs. The Large Facilities Office, as part of BFA, also provides advice and assistance to program staff and assists with agency oversight and assurance. Representatives from the above NSF offices comprise the DKIST integrated project team (IPT), which meets on a quarterly basis to discuss outstanding project issues.
- External Structure: The construction project is conducted by NSO. NSF funds NSO operations and maintenance (O&M) and DKIST design and construction via separate cooperative support agreements (CSAs) beneath an overarching cooperative agreement (CA) with the Association of Universities for Research in Astronomy, Inc.(AURA). The NSO CA and O&M CSA were recently renewed for a period of ten years through the end of FY 2024. This period covers the DKIST construction phase and the achievement of sustainable operations of the completed facility. The DKIST director is a senior NSO scientist who was a leader in the development of the science case and an expert in the field of solar adaptive optics, a critical technology for the DKIST. The project manager has experience in several other NSF-funded large projects including the Atacama Large Millimeter/submillimeter Array and the

Expanded Very Large Array. Several councils and working groups provide input from the solar and space physics communities.

Reviews

- Technical reviews: Reviews have been conducted throughout the design and development phase. The preliminary design was found to be robust in the NSF-conducted Conceptual Design Review in March 2005 and Preliminary Design Review in October-November 2006. The project has completed a comprehensive set of system-level design reviews for all major sub-systems.
- Management, Cost, and Schedule reviews: DKIST scope, schedule, budget estimate, and risk-adjusted total project cost were scrutinized and validated at the Preliminary Design and Final Design Reviews.
- Final Design Review (FDR): The FDR was held on May 18-21, 2009. The unanimous finding of the review panel was that the DKIST project was fully prepared to begin construction.
- Re-baseline review: A review of the revised project cost, schedule, and risk was held in October 2012. The project responded to the recommendations of the review panel and follow-up discussions were completed in April 2013. The new baseline was approved by NSB and the NSF Acting Director in August 2013.
- Programmatic review: A comprehensive review of the DKIST Project Execution Plan and construction progress took place December 7–9, 2015. Discussion topics included: science requirements; project performance and management controls; earned value management; risk management; integration, testing and commissioning; systems engineering; project compliance; stakeholder interactions; and project safety. The review panel debriefed NSF and the project at the end of the meeting stating, ”project performance against the plan defined in the Project Execution Plan is excellent.” The review panel’s final report was delivered in late-December 2015.
- Business Systems Review (BSR): A BSR is currently underway and is projected to last from December 2015 – March 2016.

Project Status

The DKIST project continues to make progress on construction at the summit of Haleakala on Maui, HI, while remaining in compliance with all local, state, and federal environmental and cultural requirements. The project continues to consult with various stakeholders on a regular basis including the Hawaiian Department of Land and Natural Resources, the Hawaiian Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the Federal Aviation Administration, the National Park Service, and Native Hawaiian cultural practitioners.

Construction highlights include:

- Erection of the large, rotating enclosure (dome) continues in FY 2016. The enclosure will be commissioned, declared watertight, and accepted by the end of FY 2016 (a Level 1 milestone).
- The Coudé rotator platform assembly inside the enclosure continues through FY 2016.
- The telescope mount assembly (TMA) has been shipped to Maui, and assembly of the TMA base inside the enclosure will begin in late FY 2016.
- The main M1 mirror polishing was completed in early FY 2016 (see picture below). The mirror will be stored in Tucson until 2017-2018 and subsequently shipped to Maui for integration.
- Four of the five first-light instruments have undergone critical design review (CDR) and are now in fabrication. Fabrication will continue through FY 2017. The DKIST project management team continues to work with the German KIS team to bring the fifth instrument (the VTF) back on schedule (see risks below).

In FY 2017, the Coudé rotator platform will be commissioned and accepted. The installation of the Telescope Mount Assembly (TMA) electrical systems will be completed, and commissioning and acceptance testing of the TMA will begin. The Coudé lab room will be complete and various components of the Coudé optics system installed. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered, assembled and will begin initial checkout.

Cost and Schedule

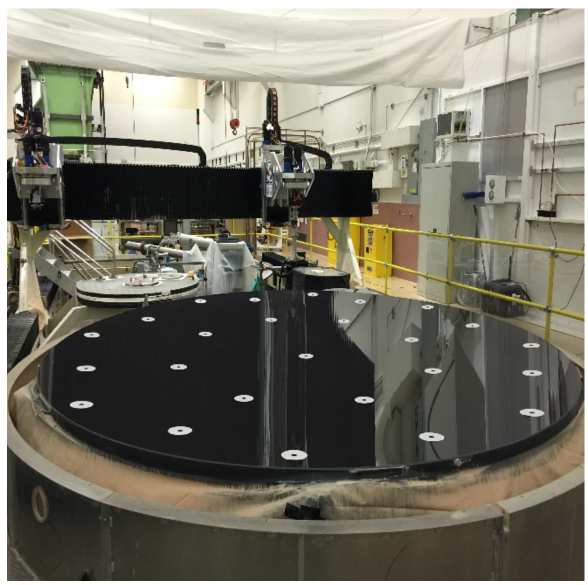
The original baseline not-to-exceed, risk-adjusted cost was established following FDR. As noted above, a revised project baseline review was held in October 2012; NSB approved the new baseline in August 2013. Total project cost of $344.13 million is derived from ARRA ($146.0 million) and annual appropriations in the MREFC account ($198.13 million). Full science operations will begin in 2019.

Risks

Project management control, interface control, and change controls are in place. The project also maintains a risk register that is reviewed and updated on a monthly basis.

Technical: The majority of the remaining technical risk is very low as a result of the long design and development phase, with the exception of one first-light instrument: the VTF described above. This instrument is an in-kind contribution from the German Kiepenheuer-Institut für Sonnenphysik (KIS) being designed and developed through a MoU between AURA and KIS. The VTF instrument has yet to pass the Preliminary Design Review (PDR) phase and there is substantial risk that the instrument will not be available at first light. The DKIST project and the managing organization, AURA, are actively managing the situation and attempting to restore the original VTF schedule.

Environmental and Cultural Compliance: AST, NSF's Office of the General Counsel, and the DKIST project have carefully worked through the applicable statutes, and a cultural monitor has been retained during construction. All required permits are in place and semi-annual consultations with a Native Hawaiian working group continue. There are two outstanding legal appeals with the potential to impact project construction; both are pending decisions in the Hawaiian Supreme Court. In a similar case involving the construction of the Thirty Meter Telescope (TMT) the Court recently (December 2015) invalidated the TMT's CDUP for failure to hold a Contested Case hearing prior to issuance of the CDUP by the Hawaiian BLNR. The DKIST project halted construction under its 2010 CDUP in order to resolve a Contested Case hearing. A second CDUP was approved in November 2012 after the resolution of the Contested Case in favor of the project. Nevertheless, the two pending appeals still represent a significant risk exposure to the DKIST project and to NSF.



The DKIST main (M1) mirror being polished at the University of Arizona's College of Optical Sciences. C*redit: R. Kneale, DKIST.*

Environmental Health and Safety: NSO has a well-developed safety program engendered in the DKIST project. The DKIST project has developed a site safety plan and conducted a thorough construction readiness review in 2011 and conducts annual safety reviews.

DKIST Operations Costs

For the sake of completeness, DKIST operations costs are listed here in the DKIST MREFC narrative; however, DKIST operations are funded through R&RA account (see the NSO narrative in the Facilities chapter for more information). As outlined in the NSO narrative, the request of $16.0 million for FY 2017 includes $11.50 million for the continuing ramp of DKIST operations, $2.50 million to partially fund the Remote Operations Building on Maui (should this alternative be selected by an ongoing environmental review process), and $2.0 million for cultural mitigation activities as discussed below. In FY 2019, the estimated steady-state operations and maintenance cost will be $16.50 million, exclusive of cultural mitigation activities. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete. NSO operating costs will be reduced through the closure or divestment of telescopes replaced by DKIST. A transition plan for the divestment of these facilities is part of the renewal of the NSO cooperative agreement and was externally reviewed.

As noted above, cultural mitigation commitments were made pursuant to terms of DKIST environmental and cultural compliance as described in the final environmental impact study and the subsequent Record of Decision and the Programmatic Agreement. These include $2.0 million of R&RA funding annually for 10 years (FY 2011 – FY 2020) for programs on Maui, supporting science, technology, engineering, and mathematics education and workforce development with an emphasis on Native Hawaiian students. A ten-year award to develop and administer these programs was made to University of Hawaii, Maui College in September 2011.

Telescope enclosure assembly underway at the DKIST site on Haleakala, Maui, HI, November 2015.
C*redit: DKIST project web camera.*

LARGE SYNOPTIC SURVEY TELESCOPE $67,120,000

The FY 2017 Budget Request for the Large Synoptic Survey Telescope (LSST) is $67.12 million. This is the fourth year of support for a nine-year project that began in August 2014. The National Science Board approved not-to-exceed total project cost is $473.0 million for NSF's contribution to the project's scope.

Appropriated and Requested MREFC Funds for the Large Synoptic Survey Telescope

(Dollars in Millions)

FY 2014 Actual	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	Total Project Cost
$27.50	$79.64	$99.67	$67.12	$55.80	$47.89	$45.75	$39.90	$9.73	$473.00

Totals may not add due to rounding.

LSST will be an 8-meter-class wide-field optical telescope designed to carry out surveys of nearly half of the sky. The initial 10-year survey has a cadence enabling repeat observation of each survey field approximately twice weekly. The requirements for LSST were defined by considering four key science areas:

- Understanding the physics of dark energy and dark matter.
- Making a census of the small bodies in the solar system, including potentially hazardous Near Earth Objects.
- Mapping the structure and contents of the Milky Way galaxy.
- Understanding the nature of transient astronomical objects on time scales ranging from seconds to years.

By satisfying the requirements defined by these key investigations, the LSST survey also will result in a comprehensive data set that will enable hundreds of other fundamental astrophysical studies by the entire research community. Thus, LSST has the potential to change every field of astronomical study, from the inner Solar System to the large-scale structure of the Universe.

Baseline History

Construction of LSST is a joint NSF/Department of Energy (DOE) effort to realize an instrument that has been in design and development for over 15 years and that was ranked as the top large ground-based astronomy project by the National Research Council (NRC) 2010 Decadal Survey.[3]

Prior to NSF's MREFC construction award, over $130.0 million was invested by NSF, DOE, and private (non-federal) partners, with about 70 percent in design and development, and 30 percent, from private funding, in early construction. The non-federal funding supported casting and polishing of the innovative combined primary-tertiary mirror (M1M3), initial site preparation, and prototype detector creation and evaluation, all of which significantly reduced construction risks.

The project was originally baselined following a series of reviews conducted by NSF and DOE in 2011 and 2012, including the NSF Preliminary Design Review (PDR) and a subsequent cost estimation review. Since that time, the construction plan has been kept up-to-date to synchronize the DOE and NSF funding profiles and adjust schedule contingency, as described below in the Cost and Schedule section.

[3] http://sites.nationalacademies.org/bpa/BPA_049810

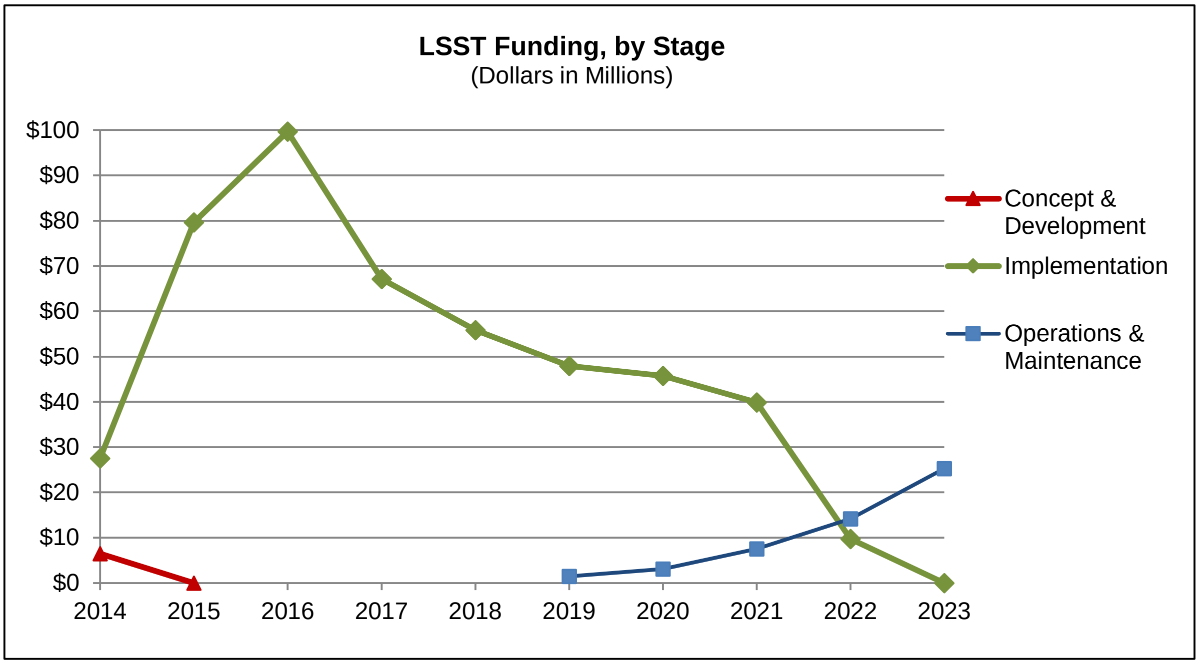
Total Obligations for LSST

(Dollars in Millions)

	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$57.13	-	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	1.49	3.10	7.50	14.13
Subtotal, R&RA Obligations	$57.13	-	-	-	-	$1.49	$3.10	$7.50	$14.13
MREFC Obligations:									
Implementation	27.50	79.64	99.67	67.12	55.80	47.89	45.75	39.90	9.73
Subtotal, MREFC Obligations	$27.50	$79.64	$99.67	$67.12	$55.80	$47.89	$45.75	$39.90	$9.73
TOTAL Obligations	**$84.63**	**$79.64**	**$99.67**	**$67.12**	**$55.80**	**$49.38**	**$48.85**	**$47.40**	**$23.86**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding begins in FY 2019.



LSST Science Plan

LSST will be an 8.4-meter primary, 6.7-meter effective aperture, special purpose optical telescope to be located on Cerro Pachón, Chile. The Chilean site was selected because of the excellent sky transparency and image quality ("seeing"), dark skies, small fraction of cloudy nights, and the geological characteristics that enable the rapid telescope motions required to carry out the LSST survey. LSST will collect nearly 40 terabytes of multi-color imaging data every night for 10 years, producing a long-lived dataset of considerable utility. It will produce the deepest, widest-field sky image ever, and issue alerts for moving and transient objects within 60 seconds of their discovery. Repeated deep imaging of every part of the accessible sky will turn up transient and explosive events such as cataclysmic variable stars, supernovae, and the optical counterparts of X-ray flashes, as well as less spectacular moving objects.

LSST data will be widely accessible, and discovery opportunities will be available to the K-12 student as well as to the professional astronomer. An innovative citizen science program will involve people of all ages in LSST discoveries. More than half of the cost during operations is for data management, including user-friendly interfaces tailored for the different anticipated communities. The survey strategy makes the same dataset usable for almost all of the astronomy community as well as for educators and the general public. The primary data archive is planned to be located at the National Center for Supercomputing Applications (NCSA) in Illinois.

Management and Oversight

- NSF Structure: NSF oversight is the primary responsibility of the LSST program officer in the Division of Astronomical Sciences (AST) working with staff from the Directorate for Mathematical and Physical Sciences (MPS) and the Office of Budget, Finance, and Award Management, which includes the Large Facilities Office, through the recently established integrated project team (IPT). The NSF program officer works closely with counterparts in the DOE Office of High Energy Physics, who have oversight responsibility for the LSST camera sub-project. Inter-agency coordination is accomplished through weekly meetings of a joint oversight group (JOG) and was formalized through a memorandum of understanding (MOU) signed in July 2012.
- External Structure: The responsible awardee for LSST construction is the Association of Universities for Research in Astronomy (AURA), Inc., a non-profit science management corporation consisting of 40 U.S. institutional members and four international affiliates. AURA works closely with LSST Corporation (LSSTC), which initiated LSST development and remains responsible for privately raised funding. AURA and LSSTC established the LSST Project Office as an AURA-managed center for the construction period; this office is overseen by the AURA Management Council for LSST. The LSST project director and the LSST project manager are experienced in large facility construction and operation and are appointed by AURA, with the involvement and approval of LSSTC and NSF.

Reviews

- Technical Reviews: Reviews were conducted throughout the design and development phase, culminating in NSF's Final Design Review (FDR) in December 2013, with DOE involvement. All major sub-systems undergo regular system-level design reviews organized by the LSST Project Office with external participants.
- Management, Cost, and Schedule Reviews: Cost, schedule, and risk are also scrutinized by the technical reviews. During construction, NSF and DOE are holding regular joint progress reviews.
    - NSF held a recommended Joint Interface & Management Review (with DOE), and a separate Cost Estimation Review, both in May 2012. DOE held a camera status review in June 2013.
    - Subsequent to FDR, the National Science Board (NSB) authorized NSF management to proceed with the construction award on May 7, 2014 (NSB-14-24), subject to additional cost and management scrutiny.
    - An NSF internal cost analysis from 2013 was followed up by a Cost Estimation Sufficiency Review conducted by an independent contractor, which reported in April 2014. Both reports found the LSST Project's Basis of Estimate documentation to be adequate at the time of review, with small improvements requested. NSF secured those additional items from the awardee prior to making the MREFC award in August 2014. Contingency estimates were finalized in April 2015 in accordance with latest NSF policy.
    - The first annual construction review is planned for February 2016.
- As a result of two DOE Critical Decision (CD) reviews, DOE issued CD-3a approval for long-lead procurements in July 2014, and CD-2 approval, including setting the not-to-exceed Total Project Cost for the DOE sub-project, on January 7, 2015. CD-3 review in early August was followed by formal approval for full DOE construction funding on August 27, 2015.

Project Status

NSF's construction award was issued on August 1, 2014. The project worked closely with NSF's Division of Acquisition and Cooperative Support (DACS) to resolve all major cost issues, in accordance with the

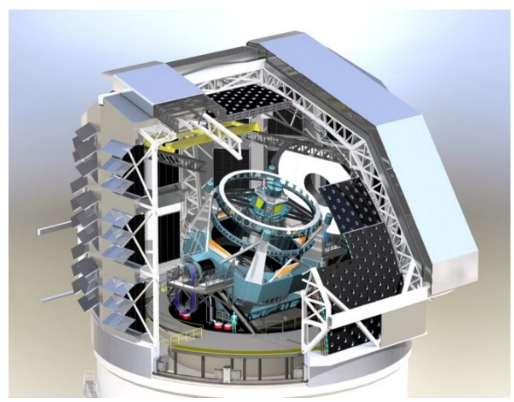
NSB resolution, as detailed below. Major work packages for the telescope mount assembly and for the summit facility were contracted early in FY 2015, quickly followed by contracts for the dome construction, secondary mirror polishing, the camera support systems, and the M1M3 support cell. The base facility and Chilean data center, and the coatings plant, were subject to bid request, review, and selection in FY 2015, and contracts are being negotiated in early FY 2016. Updates to the U.S. data center contract were also approved. The critical M1M3 mirror passed its acceptance tests early in CY 2015 and was carefully coated and crated for storage until needed in Chile. DOE funding supported continued detector development and initial procurement, an important milestone for the camera. Contracts have started for the major lens systems and for the detector support system. NSF- and DOE- supported activities remain tightly coordinated, both at the project level and between agency program officers.

While the facility, telescope, and camera are being built, the project will continue to address data access, computation, and collaboration needs. Because there will be different communities of users, there will be various concurrent modes of access. Development of the data access policy is a continuing activity as multiple promising approaches exist; the details continue to be the subject of very active discussion within the project, with internal and external advisory committees, and with potential international partners.

<u>Cost and Schedule</u>

There was a complete bottom-up re-planning of the project prior to the NSF FDR. The FDR panel found the NSF Total Project Cost (TPC) of $473.0 million to be reasonable and justifiable, assuming the project introduced some additional de-scoping options. The resulting project schedule and TPC were predicated on a July 1, 2014 start for MREFC funding from NSF. While the actual date was August 1, 2014, this slight delay has not had a significant impact.

Because of changes in NSF's requirements for the estimation of project contingency, the initial award contained only a limited obligation for that purpose. The project established the new contingency methodology throughout their project management control system and calculated a risk-based joint cost and schedule analysis, in close consultation with NSF's Large Facilities Office. The revised amount, at almost the same number as provided at FDR, equates to a better than 90 percent chance of coming in on schedule and within the sum of base plus contingency. This revision was presented to NSF for review. After provision of updated explanatory material, the award was amended in April 2015 to authorize the new level of contingency for the full project duration.



Cutaway of dome showing telescope within. *Credit: LSST.*

NSF recently revised its policy on the use and oversight of management fees. Negotiations between AURA and NSF on the fee are ongoing, but the final fee will come within the approved total project cost.

In addition to NSF's contribution, DOE's baseline for the camera has been fixed at $168.0 million. Construction includes $38.97 million from non-federal sources, nearly all of which has been expended.

<u>Risks</u>

Technical: Much of the technical risk has been retired by completed design and development efforts and by investment of non-federal funds in construction, notably for the primary-tertiary mirror, completed in early CY 2015. Both PDR and CD-1 external reviews identified the camera detectors as a possible risk; this risk continues to be reduced and the project mitigation strategy was again endorsed by a DOE-led status review in June 2013. The risk registry is continually monitored and updated.

Environmental and Cultural Compliance: The Chilean environmental and cultural impact assessment was completed and reviewed and subsequently approved by NSF in October 2010, under Executive Order 12114 for extraterritorial projects. Mitigation work continues, with the propagation of threatened plant species and their subsequent reintegration at the site.

Site: The above environmental and cultural impact assessment, and the subsequent finding equivalent to no significant impact, cleared the way for the preliminary site work. Local contractors leveled the planned location for LSST and confirmed the geological results from the original test borings. They found no problems that could compromise the overall stability and rigidity of the mount as currently designed. The only remaining site risks are local geological anomalies that can be mitigated through footer/foundation modifications and the use of contingency.

Environmental Health and Safety: The LSST project has a full-time head of safety with experience in AURA operations, which has a long positive safety record in Chile. AURA safety policy encompasses general guidelines as well as site-specific policies, such as a LSST summit-specific plan. These plans are fully compliant with applicable standards from U.S., Chilean, and participating institutions. The plans will be monitored and updated appropriately and will be reviewed annually.

Partnership Risk: The LSST project director oversees the entire project and is assisted by a deputy project director who started on September 1 2015, with complementary skills and experience. Detailed project management is handled by a single project manager, agreed to by both NSF and DOE program management. Budgetary management details are clearly set out between the project director, the project manager, the project's Change Control Board, the AURA Management Council for LSST, and the agency program officers, grants officers, and financial managers. The commitments by DOE and by NSF were officially recorded in an MOU between the agencies that was signed in July 2012. As the MOU notes, the management structure treats the project as a single team and includes mechanisms and authority to make changes on either side of the DOE/NSF budgetary boundary, and across that boundary, if needed.

Operations Costs: A formal proposal for LSST operations, being drafted and agreed to amongst the planned operational partners, will be submitted jointly to NSF and DOE about two years before planned early operations. Proposal review will result in the baseline project execution plan and operating costs. The project team has focused on finding partners willing to contribute to the necessary non-federal contribution of approximately $9.0 million per year. Letters of commitment have been received from 68 institutions in 26 countries for a total annual contribution of over $10.0 million. Negotiations have started for firm agreements and possible advance contributions. A LSST@Europe meeting in September 2013 included attendees from 20 countries and led to detailed discussions about those contributions and agreements; a second such meeting is scheduled for June 2016. Given the signed NSF/DOE MOU and the high level of signatories to the partner letters of commitment, operational support risk is low. The LSST Project Office will form an international finance committee to oversee the use of contributed operating funds.

Future Operations Costs

Estimated full operations costs in FY 2013 U.S. dollars were $36.63 million per year at the time of FDR. Following the recommendation of the NRC 2010 Decadal Survey, AST has planned to provide approximately 50 percent of that amount, as well as early operations support ramping up to the full contribution. The DOE Office of High Energy Physics has committed to another 25 percent. The project has started a new analysis to update and verify the cost estimation as part of preparing their operations proposal. The total annual cost, and the amount required from the non-federal partners, will be determined during the review of that proposal, which may lead to updates in the notional operations numbers presented above for FY 2019 and beyond. In the joint MOU, NSF and DOE agreed together to funding operations, increasing agency support, and/or revising the operations plans, as appropriate.

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK $0

No MREFC funds are requested for the National Ecological Observatory Network (NEON) in the FY 2017 Request. The FY 2016 Request was the final year of construction funding for the six-year project that totals an estimated $433.72 million. Construction is expected to be complete at the end of FY 2017. NEON operations and maintenance will be funded through the Directorate for Biological Sciences.

Appropriated and Requested MREFC Funds for the National Ecological Observatory Network

(Dollars in Millions)

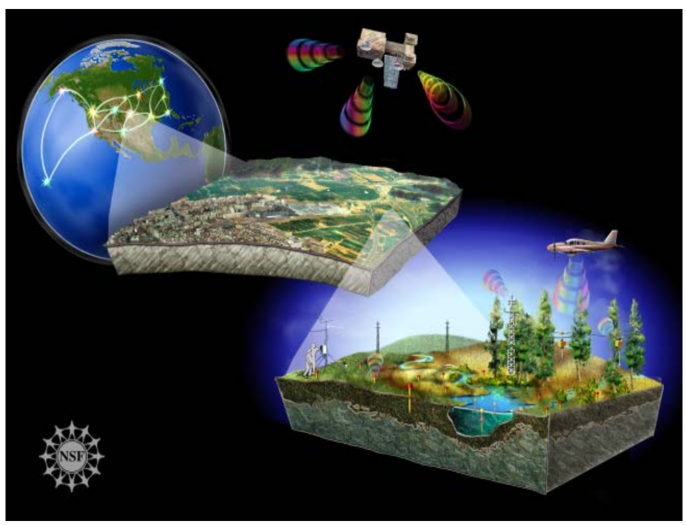
Prior Years	FY 2012 Actual	FY 2013 Actual	FY 2014 Actual	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Total Project Cost
$12.59	$60.30	$91.00	$93.20	$96.00	$80.64	-	$433.72

Totals may not add due to rounding.

NEON consists of geographically distributed field and lab infrastructure networked into an integrated research platform for regional to continental scale ecological research. Cutting-edge sensor networks, instrumentation, experimental infrastructure, natural history archive facilities, and remote sensing will be linked via the internet to computational, analytical, and modeling capabilities to create NEON's integrated infrastructure.

Baseline History

In 2004, the National Research Council (NRC) evaluated the original NEON design of loosely confederated observatories and recommended that it be reshaped into a single integrated platform for regional to continental scale ecological research. Congress appropriated initial funding in FY 2007. A Preliminary Design Review (PDR) was completed in June 2009 and a Final Design Review (FDR) was completed in November 2009. The FDR also included a formal construction baseline review and cost review; an additional baseline review was conducted in April 2011 prior to initiation of construction that confirmed the baseline scope, cost, and schedule. Project planning continued through FY 2011 until construction began in August 2011.



NEON will be a collaborative research platform of geographically distributed infrastructure connected via the latest information technology. By combining in-situ sensing with remote sensing observations, NEON will address pressing environmental questions on regional to continental scales. *Credit: NSF.*

Total Obligations for NEON

(Dollars in Millions)

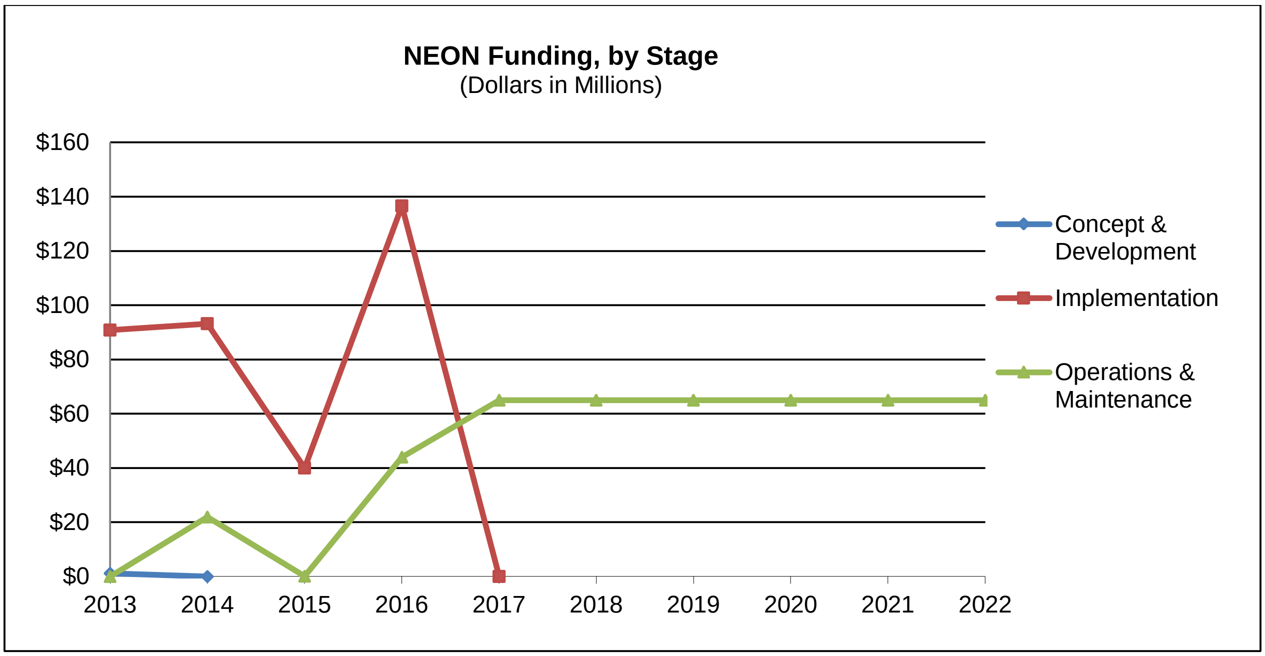
	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$91.73	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	21.89	0.12	44.04	65.00	65.00	65.00	65.00	65.00	65.00
ARRA	9.96	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$123.58	$0.12	$44.04	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00
MREFC Obligations:									
Implementation[3]	257.08	40.00	136.64		-	-	-	-	-
Subtotal, MREFC Obligation	$257.08	$40.00	$136.64	-	-	-	-	-	-
TOTAL Obligations	**$380.66**	**$40.12**	**$180.68**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.

[2] Funding for Operations & Maintenance (O&M) in outyears has been capped at now-year dollars, pending the results of a three year initial O&M testing. A final O&M award, to be made after the three years concludes, will reflect these results.

[3] FY 2016 MREFC obligations include $56.0 million carried over from FY 2015.



NEON is the first research platform and the only national experimental facility specifically designed to collect consistent and standardized sensor and biological measurements across 82 sites nationwide, representing a reduction from 106 sites following descoping. Measurements will be collected in close to real-time, enabling basic research on complex phenomena driving ecological change and at the scales appropriate for studying many grand challenge questions in ecology. NEON allows researchers to expand the scale of their research to understand large-scale dynamics affecting ecosystems.

A NEON cyberinfrastructure gateway provides resources to support formal and informal public education and provide opportunities for citizens to participate in scientific investigations. NEON data is open-access via web portals and available as soon as possible, once basic quality assurance and quality control procedures have been applied. Private organizations including the Heinz Center, National Geographic Society, Nature Serve, and the Ecological Society of America are assisting NEON, Inc. to broaden the impact of NEON science and education to the next generation of scientists and educators.

The 2009 United States Global Change Research Program (USGCRP) assessments[4] indicate that U.S. ecosystems will experience abrupt and unpredictable changes from a suite of human-driven processes in the near future. NEON enables research on the impacts of climate and land use change, water use, and invasive species on the Nation's living ecosystems at temporal and spatial scales that are relevant to human well-being. NEON's unique statistically-determined, continental-scale design, with data products, data management, and standardization supports research on the dynamics of complex coupled systems needed for modeling and understanding rates of change on regional and continental scales. No other standalone system – federal or private – can provide the scientifically validated suite of data measurements that NEON will provide.

The scientific techniques, sensor data, and basic research knowledge gained through NEON will inform federal resource management decisions necessitated by climate and land use change, water use, and invasive species. They will contribute to societal benefits as identified by the 2014 U.S. National Plan for Civil Earth Observations[5] and the international Group on Earth Observations 2005 Framework Document.[6] The science that NEON supports is not bound by national boundaries, with regard to climate change, invasive species, and the ecological processes they affect. The repurposing of NEON data and information and establishing interoperability among all earth observations is important to enable the research on continental to global scales. Domestic and international MOUs focus on meeting NEON's Strategic Plan and the U.S. National Plan for Civil Earth Observations[2] both of which call for strengthening international collaboration in earth observations, and to improve data access, management, and interoperability. Formal agreements have been signed with the European Union, including the Integrated Carbon Observing System (ICOS) Ecosystem Thematic Center, Infrastructure for Analysis and Experimentation on Ecosystems (AnaEE), Czech Climate Change Research Center (CzechGlobe), and Australia's Terrestrial Ecosystem Research Network (TERN). Areas of coordination include planning, design, construction, deployment, environmental assessment, data management, geospatial data exchange, cyberinfrastructure, research, and modeling. As described in an August 2013 article in the *Engineering News-Record*,[7] NEON construction models are also having an impact on establishment of new standards for construction in environmentally sensitive areas.

Management and Oversight

- NSF Structure: The NEON program is managed by the Division of Biological Infrastructure (DBI) within the Directorate for Biological Sciences (BIO). Managing the NEON program in DBI helps foster its associations with other BIO facilities and infrastructure investments and its connections to

[4] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

[5] The US National Plan, which states '…to coordinate, plan, and assess Federal Earth observation activities in cooperation with domestic stakeholders; to foster improved Earth system data management and interoperability throughout the Federal Government; and to engage international stakeholders by formulating the U.S. position for, and coordinating U.S. participation in the intergovernmental Group on Earth Observations.' Holdren, J., T. Dickenson, G. Paulson, et al. 2014. *National Plan for Civil Earth Observations*, National Science and Technology Council, Executive Office of the President, pp. 71. www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf

[6] Group on Earth Observations, Global Earth Observation System of Systems (GEOSS): 10-Year Implementation Plan Reference Document, 2005, www.earthobservations.org/documents/10-Year%20Plan%20Reference%20Document.pdf

[7] http://enr.construction.com/technology/construction_technology/2013/0828-reaching-zero-the-realities-of-ecologicallyfriendly-engineering-on-a-continental-scale.asp

broader biological and interdisciplinary science activities. Within BIO/DBI, a senior Science Advisor (working with the Deputy Division Director) provides overall programmatic oversight for BIO's mid and large scale facilities, while the day-to-day program management is done by a dedicated cognizant program officer with assistance from a program manager experienced with other MREFC projects. Two additional program officers and a project manager assist with planning, development, and oversight of NEON construction, operations and maintenance, and science. An NSF Integrated Project Team (IPT) chaired by the NEON program officer, with representatives from the Large Facility Office (LFO), the Division of Acquisition and Cooperative Support (DACS), and program representatives from other NSF large facilities, provides coordinated agency oversight to the project. The Office of the General Counsel provides ongoing technical advice on the National Environmental Policy Act (NEPA) compliance and NSF environmental policy and also has representation on the IPT. Funding for NEON remains in Emerging Frontiers (EF), a BIO-wide interdisciplinary virtual organization, until funding for a new NEON managing organization (see below), and associated final costs, are determined. The findings of an external cost review are expected mid-March 2016; a decision on a new managing organization is expected by the end of March 2016.

- External Structure: NSF is currently seeking a new managing organization to oversee the construction and initial operations of NEON. A transition in management structure will occur in early 2016. Currently the NEON project is funded through cooperative agreements with NEON, Inc., a non-profit, membership-governed corporation established to manage the design, construction, and operation of NEON for the scientific community. Scientific community oversight will also be revisited as part of the management transition. NEON, Inc. was notified in December 2015 of NSF’s intent to transfer responsibility for construction and initial operations to a new management entity.

Reviews

- Technical reviews: The NEON Observatory Design Review (including site selection and deployment design) was successfully completed in February 2009.
- Environmental review: The NEPA environmental assessment was completed in November 2009. NSF signed a “Finding of No Significant Impact” in December 2009; the U.S. Fish and Wildlife Service concurred with this finding, as well as with NSF’s compliance with the Endangered Species Act. In July 2011, the NSF Record of Decision was signed.
- Construction, Cost, and Schedule reviews:
  - A Conceptual Design Review was held in November 2006.
  - A combined Preliminary Design Review (PDR)/Final Design Review (FDR) of the airborne observation platform was successfully completed in February 2009.
  - A PDR for the entire project was successfully completed in June 2009.
  - An FDR was successfully completed in November 2009, including construction and cost reviews.
  - A Baseline Review, to ascertain readiness to begin construction, was conducted in April 2011 prior to construction.
  - A second Baseline Review was held May 2013 to ascertain the impacts of funding delays on project schedule. A Delta Review – to assess progress in implementing scheduling recommendations received from the baseline review panel – was held in December 2013.
  - A third Baseline Review was held in August 2014 to evaluate re-planned schedule and cost.
  - NEON, Inc. was notified in May 2015 of non-compliance with terms and conditions of the cooperative support agreement, NSF’s concerns over increasing schedule slippage, required delivery of a new estimate to complete the project, and NSF’s intent to conduct strategic assistive site visits.
  - In June 2015 the NEON, Inc. estimate to complete included a projected cost overrun of $80 million above the approved budget. A baseline Re-Scope Review was held in July 2015 to assess

reductions in scope to bring the costs within the approved budget in accordance with NSF's "No Cost Overrun" policy.
- NEON, Inc. was notified in July 2015 to reduce the NEON scope and deliver revised project documents, construction schedule, and cost proposal to reflect the scope reduction.
- A Revised Cost and Schedule Proposal was submitted December 2015 which indicated the potential for an additional $19.0 million cost overrun and further schedule slip leading NSF to make its decision to transfer management responsibility.
- An independent cost estimate is being obtained by NSF to support its internal cost analysis and award to the new managing organization.
- A Construction Review will be conducted annually.

- National Science Board (NSB) Review: The Board reviewed and authorized NEON construction subject to final appropriation of funds in May 2010. The Board reviewed and authorized NEON Operations and Maintenance (O&M) in February 2013. In September 2015 the Board established an ad hoc Task Force on NEON Performance and Plans to review the Board's and NSF's processes associated with NEON project management and oversight.
- Management, Business, and Operations Reviews:
  - NSF conducted a Business Systems Review (BSR) and issued a final report in November 2011.
  - An Operations Review of the project's operating plan and costs for the first three years of operations was held in January 2012.
  - Beginning in May 2015, NSF has conducted a series of site visits to work with NEON, Inc., on improving business systems including reporting capabilities, cost sufficiency and estimation, and supply chain issues including procurement and contracting.
  - In December 2015 NSF notified NEON, Inc. of its intent to transfer responsibility for construction and initial operations to a new management organization. The transfer is planned to occur in early 2016 following the NSF cost analysis and negotiations with the new organization.
  - With the transition to a new management organization, an extension of the initial operations award is anticipated to allow the project to stabilize. A pre-award cost review prior to full observatory operations funding is expected in FY 2018.
  - Operations and management reviews will be conducted annually starting in FY 2016; delays in construction have impacted rollout of operations by one year.

Project Status

In September 2013, the construction of technical support facilities was completed and used to support other construction activities before transitioning to operations in FY 2015. NEON's airborne observation platform (AOP) provides remote sensing through aircraft-mounted instrumentation, including an imaging spectrometer operating in the visible to shortwave IR spectral region, a waveform light detection and ranging (wLiDAR) instrument, and a high-resolution digital camera deployed on three aircraft. The first two airborne observatories were constructed with NASA missions conducted in FY 2013 along with research studies on management of major forest fires. The third airborne observatory was delivered ahead of schedule in FY 2014. The three airborne observatories are being flight tested and verified to transition to operations in FY 2016 with completion occurring in FY 2017.

Construction of distributed infrastructure and deployment of sensor assemblies is underway. Procurement and production difficulties have led to delays in some higher-level sensor assemblies. Thirty percent of the Observatory research capabilities were available in July 2015, and 60 percent are expected by the end of FY 2016. While 100 percent capability is planned by the end of FY 2017, delays in production, deployment, and permitting may postpone some deliverables by a year or more. In FY 2016, construction activities are planned to be completed for 25 terrestrial sites. Observatory construction for the remaining 23 terrestrial locations is currently planned to be complete in FY 2017, but may require a few additional months in early

FY 2018. Construction of 16 aquatic sites will be complete in FY 2016 with the remaining 18 planned to be complete in FY 2017.

In FY 2017, MREFC funds will support completion of the NEON cyberinfrastructure hardware and software deployments for various sites as well as domain facilities acceptance. This includes completion of the management system for assets, configuration, inventory, and data algorithms and related data release via NEON's web portal.

Scope Management and De-scoping: Delays in permitting of selected sites, cyberinfrastructure development, and procurements signaled the potential for significant construction cost overruns. Estimates received in June 2015 prompted NSF to assemble leaders from the science community to assess possible scoping strategies for maintaining the project with the approved budget in accordance with NSF's No Cost Overrun policy. A major objective of the meeting was to ensure the delivered Observatory would still enable the transformative regional to continental science as framed in the original NEON Science Strategy. This decision to de-scope was confirmed by the NSF/BIO Advisory Committee. Descoping decisions were finalized and implemented in late July 2015. Revised project documentation including a new cost proposal and schedule-for-completion was delivered in early December 2015. An independent cost review is underway, to be completed in March 2016.

In FY 2017, $65.0 million is requested from the Research and Related Activities (R&RA) account for operations and maintenance (O&M). This represents the final increment from the original three-year O&M award as well as a partial increment for a proposed one-year extension. This additional year in prototype O&M will allow time for a more complete understanding of the services and costs proposed and to prepare for a re-competition for a longer term award. This includes management and technical support, seasonal biological sampling, analytical and archival costs, and domain facilities costs. Funds will also support the calibration and validation laboratories and headquarters functions, such as maintenance of the data center, Observatory monitoring, quality assurance and control, and O&M of the Airborne Observation Platform. In FY 2017, NSF will explore options for operation and maintenance of the full NEON Observatory after construction.

Cost and Schedule

The original projected length of the construction project was six fiscal years, with six-months of schedule contingency included. NEON is now roughly 60 percent complete based on expenditures, with Observatory capability at 30 percent complete. Current project performance, based on an updated cost and schedule for completion developed by NEON management, is running well behind the original plan. Focused scope management and oversight is now required to remain within budget.

Risks

Technical: Technological maturity of commercial sensors, incorporation of sensors into sensor assemblies, production of sensor assemblies, and integration into NEON towers are affecting field deployments and Observatory capabilities. In FY 2015, two planned sensor systems were determined not feasible for deployment and no alternatives are currently available. These sensor systems will be deferred until operations when the technologies are more mature. While the bulk of NEON's infrastructure and instrumentation will be "commercial off-the-shelf," NEON's scientific and networking design required certain technological innovations for a small number of components. Consequently, BIO has provided R&RA funds for advanced research and development activities in the areas of sensors, cyberinfrastructure, and remote sensing technology. These development activities are progressing and risks to schedule are being monitored.

Deployment: Environmental assessment and permitting continues to impact schedule. Risk mitigation strategies include the direct contracting of the environmental assessment by NSF, the hiring of national firms by NEON, Inc. for engineering and permitting, and the identification of alternative sites if primary sites are determined to have significant risk. Some sites were identified as "unable to be permitted" and were part of the scope management actions taken in July 2015. The selection of alternative sites for other high-risk sites is nearing completion and environmental compliance activities are underway.

Management: NSF has determined that it has low confidence in NEON, Inc's ability to effectively manage the project going forward based on the December 2015 deliverables. Evaluation of alternative management organizations is underway.

Future Operations Costs

NEON is the first research observatory that will maintain and operate in-situ instrumentation and conduct biological sampling in twenty domains (82 locations) including three airborne observatories, a central operating facility and a cyberinfrastructure center. Support will be provided to monitor the sensors, and receive, process, and archive data from all measurement systems. NEON operations include significant labor costs due to the manual processes still required for biological sampling and data collection in some fields. NEON is reliant on sensors and cyberinfrastructure that have a defined lifecycle, so operations costs include scheduled replacement and refreshing of sensor, instrumentation, and cyberinfrastructure technology. Operations will ramp up as sites are commissioned. As part of the scope management plan, sites and infrastructure transition-to-operations will accelerate whenever possible.

A three-year initial award for O&M began September 2014 to allow NEON to explore opportunities for schedule and cost efficiencies and provide a basis for funding the full Observatory operations during out years. A delay in construction has extended that award from FY 2016 through mid-FY 2017, and an extension of the initial operating period is likely under new management to allow the project to stabilize. For FY 2018 – FY 2022, the planned O&M budgets are capped at $65.0 million. O&M will be revised as needed to accommodate that cap.

REGIONAL CLASS RESEARCH VESSELS $106,000,000

The FY 2017 Budget Request for the Regional Class Research Vessel (RCRV) project is $106.0 million. This represents the first year in a three-year funding profile, with an estimated total project cost of $255.50 million.

Appropriated and Requested MREFC Funds for the Regional Class Research Vessel Project

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	Total Project Cost
-	-	$106.00	$105.00	$44.50	$255.50

Totals may not add due to rounding.

The RCRV project will fund construction of two ships to meet anticipated ocean science requirements for the U.S East Coast, West Coast, and Gulf of Mexico. The 2015 National Academies of Science report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*[8], described eight high-priority science questions, all of which will be supported by RCRV in U.S. coastal waters:

1. What are the rates, mechanisms, impacts, and geographic variability of sea level change?
2. How are the coastal and estuarine ocean and their ecosystems influenced by the global hydrologic cycle, land use, and upwelling from the deep ocean?
3. How have ocean biogeochemical and physical processes contributed to today's climate and its variability, and how will this system change over the next century?
4. What is the role of biodiversity in the resilience of marine ecosystems and how will it be affected by natural and anthropogenic changes?
5. How different will marine food webs be at mid-century? In the next 100 years?
6. What are the processes that control the formation and evolution of ocean basins?
7. How can risk be better characterized and the ability to forecast geohazards like mega-earthquakes, tsunamis, undersea landslides, and volcanic eruptions be improved?
8. What is the geophysical, chemical, and biological character of the subseafloor environment and how does it affect global elemental cycles and understanding of the origin and evolution of life?

Baseline History

The RCRV project is a major component in the plan for modernizing the U.S. Academic Research Fleet (ARF).[9] In 2001, a report from the Federal Oceanographic Facilities Committee documented the need for up to three Regional Class vessels. In 2004, NSF and the Naval Sea Systems Command (NAVSEA) entered into an interagency agreement that resulted in two candidate designs for Regional Class ships. In 2007, the Federal Oceanographic Fleet Status Report identified the need for up to three NSF-built Regional Class vessels to meet future science demand. In 2009, another National Academies of Science report, *Science at Sea*, described the desirable characteristics of a modern Regional Class vessel. These characteristics and other science community factors were considered by the review panel when the preferred NAVSEA design was later down-selected. In 2012, NSF issued a solicitation for the refreshed design and potential construction of RCRVs under the MREFC process, and Oregon State University (OSU) was selected as the awardee. Input from external review panels, the University National Oceanographic Laboratory System

[8] The National Academies of Science. Sea Change: 2015-2025 Decadal Survey of Ocean Sciences, 2015. www.nap.edu/read/21655/chapter/1

[9] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013. www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

(UNOLS), and the *Sea Change* report informed the final decision to pursue construction of two RCRVs. The National Science Board approved inclusion of funds to construct two RCRVs in future budget requests at the NSF Director's discretion. Prior to an MREFC award for construction, the RCRV project will complete a Final Design Review, which is scheduled for Fall 2016.

Total Obligations for RCRV

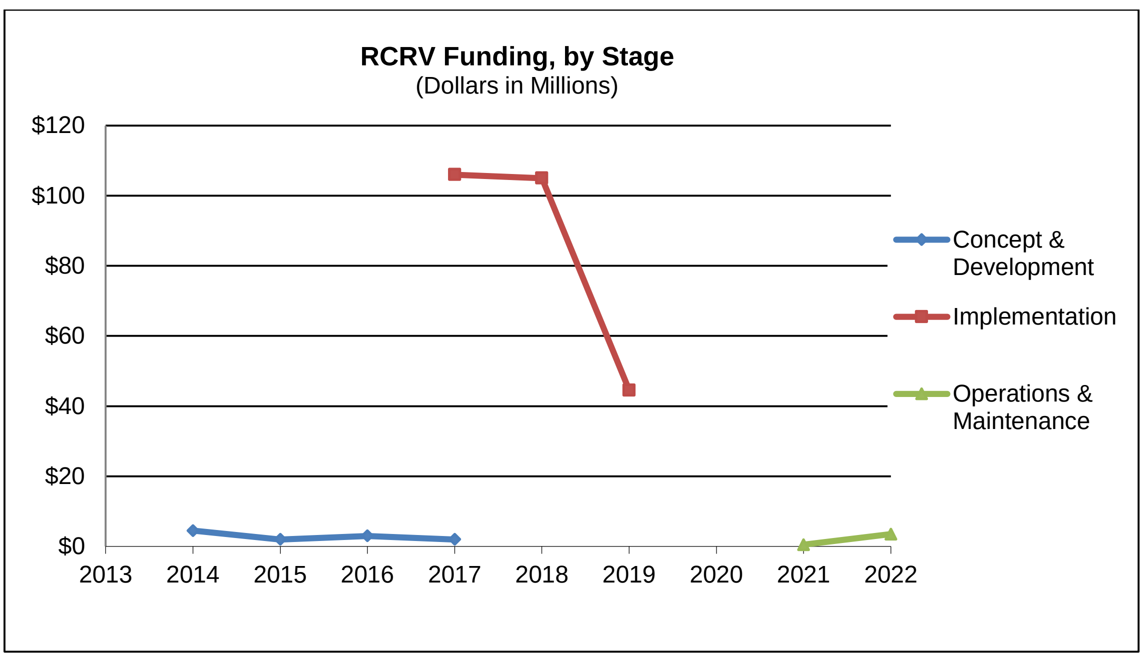
(Dollars in Millions)

	Prior Years[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
R&RA Obligations:									
Concept & Development	$4.49	$2.13	$3.00	$2.00	-	-	-	-	-
Operations & Maintenance[2]	-	-	-	-	-	-	-	2.00	3.50
ARRA	-	-	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$4.49	$2.13	$3.00	$2.00	-	-	-	$2.00	$3.50
MREFC Obligations:									
Implementation	-	-	-	106.00	105.00	44.50	-	-	-
Subtotal, MREFC Obligations	-	-	-	$106.00	$105.00	$44.50	-	-	-
TOTAL Obligations	**$4.49**	**$2.13**	**$3.00**	**$108.00**	**$105.00**	**$44.50**	**-**	**$2.00**	**$3.50**

Totals may not add due to rounding.

[1] Concept & Development funding and Implementation funding are cumulative of all prior years.

[2] Operations and Maintenance (O&M) for the RCRV project will be included in funding for the Academic Research Fleet. Because the Academic Fleet is operated as a shared multi-agency resource where agencies pay for time use on vessels, the annual operating budget may vary significantly from year to year. Thus, estimates for O&M are provided as a rough guide of likely costs. RCRV is expected to begin O&M funding in late FY 2021.



Management and Oversight

- NSF Structure: The RCRV project is overseen by the Division of Ocean Sciences (OCE) as part of the Ship Acquisition and Upgrade Program. OCE provides overall interdisciplinary science community guidance and oversight, while the location of the RCRV project in the Integrative Programs Section promotes science facilities support expertise and coordination. Within NSF, RCRV project oversight is managed by a dedicated program officer with support from a secondary program officer who has experience with other OCE facilities. Cross-foundation coordination is provided by an integrated project team (IPT). The IPT includes staff from the Office of Budget, Finance, and Award Management (BFA), the Large Facility Office (BFA/LFO), the Division of Acquisition and Cooperative Support (BFA/DACS), the Division of Institution and Award Support (BFA/DIAS), the Office of the Director (OD), the Office of the General Council (OGC), the Office of the Assistant Director for Geosciences (OAD/GEO), and the Office of Legislative and Public Affairs (OLPA).

- External Structure: The RCRV project is funded through a cooperative agreement with Oregon State University (OSU) to manage the design refresh (Conceptual, Preliminary, and Final Designs), construction, testing and trials, and eventual operation of the first RCRV for the scientific community. The principal investigator for the award is the project scientist (PS), who reports directly to OSU leadership. The PS interacts directly with NSF and manages the RCRV administrative staff. The project manager (PM) is a co-PI on the award and reports directly to the PS. The PM manages the core RCRV team including the risk manager, earned value management and schedule specialist, contracting officer, and OSU shipyard representative (SR). The SR in turn manages the naval architect and engineering contract and oversees the OSU shipyard staff, and marine science technical advisors. The RCRV Science Oversight Committee (SOC) with regional representation, multidisciplinary expertise, and science representatives conducting research in mission areas supported by stakeholder federal agencies (e.g., NSF, Office of Naval Research (ONR), and the National Oceanic and Atmospheric Administration (NOAA)) will be active through all project phases. This committee provides guidance to the OSU RCRV project team through the PS and/or the NSF program officer.

Reviews

- Proposal Review: In 2012, NSF issued Solicitation 12-558, Construction of Regional Class Research Vessels, to select a lead institution for construction of up to three RCRVs, with the option to operate one of the ships. An NSF external review panel was convened to evaluate three proposals, and Oregon State University (OSU) was selected.
- Interim Design Review (IDR): Although an Interim Design Review (IDR) was not required by NSF, OSU hosted an IDR on July 23-25, 2013, in Corvallis, OR. NSF program staff assessed the OSU project team performance and concluded the IDR followed closely the NSF requirements, and used the R/V *Sikuliaq* example, as appropriate, to craft the RCRV Project Execution Plan (PEP). Both the design and the PEP were well-developed at this pre-Conceptual Design Review phase; particularly the organizational structure, work breakdown structure (WBS), risk management, and configuration and contingency management.
- Conceptual Design Review (CDR): CDR was conducted December 3-5, 2013, at NSF Headquarters in Arlington, VA. The NSF program staff concurred with the panel's conclusion that the Project Execution Plan and Technical Design Package met, and in some cases exceeded, the requirements of the Conceptual Design Phase.
- Preliminary Design Review (PDR): PDR was conducted August 5-7, 2014, at NSF Headquarters. The panel found that the Project Execution Plan and the technical design package were both well-developed for the PDR phase and recommended that the project proceed to the Final Design Phase.
- Post-PDR Reconciliation: Following PDR, in response to the panel recommendations and NSF program staff direction, OSU incorporated modifications to the design and revised their estimated

program costs and schedule accordingly. The NSB was presented with the post-PDR Project baseline as the basis for their authorization to request funding for two RCRVs in future budget requests.

- Acquisition Strategy Review: A review of all aspects of the shipyard selection process is scheduled for February, 2016. A subset of the PDR panel will perform the review at NSF.
- Interim Design Review (IDR): A second IDR is scheduled in May 2016. Although not required, the value of the previous IDR for improvement to the technical package and the Project Execution Plan was sufficient that another IDR to prepare for FDR is warranted. The review will be hosted by the RCRV Project Team in Corvallis, OR, and will be attended by NSF program staff as well as the RCRV Science Oversight Committee.
- Final Design Review (FDR): FDR is anticipated in Fall 2016 to ensure that anticipated project costs remain realistic and that no unforeseen events have arisen prior to the start of construction during FY 2017. Like CDR and PDR, FDR will be conducted in compliance with NSF's Large Facilities Manual.

Project Status

As stated above, OSU was selected as the lead institution. A cooperative agreement (CA) was awarded to encompass the entire project, including tests and trials. The project was divided into four distinct phases; each to be funded through separate cooperative support agreements (CSA), with award of each phase contingent upon successful completion of the prior phase. These phases are:

Phase I - Project Refresh (Years one to three)
Phase II - Shipyard Selection (Year four)
Phase III - Construction (Years five to nine)
Phase IV - Transition to Operations (Years eight to ten)

The project is in Phase II during CY 2016, during which bids for construction of two RCRVs will be solicited from U.S. shipyards. Through FY 2016, funding is expected to be $9.62 million.

Cost and Schedule

The projected length of the project is ten fiscal years, including a six-month schedule contingency. Funding for the construction of two ships over three fiscal years would support a shipyard contract structure that stipulates an initial ship, plus the option for a second ship. This approach preserves funding flexibility while maximizing shipyard efficiency by potentially having both ships under construction concurrently, but at different stages.

Risks

Bid Risk: OSU provided a bottom-up cost estimate for two vessel construction using various escalation rates. No additional "buffers" or "reserve" are added to the bottom-up estimates. Hull construction uncertainty is addressed by the risk register, and associated contingency per NSF policy on contingency estimating and use. There is a risk that shipyards may respond to the RFP with bids that exceed the estimation. The base estimates from OSU were validated by expert panel review as well as through comparison with an independent cost estimate commissioned by NSF.

Technical: It may be the case that the desired low ship self-noise levels are not initially achieved. Contingency funds are included if a secondary noise mitigation strategy is required to meet the ship specifications. It may also be the case that sonar sensors, science load handling systems and other vessel sub-systems do not perform as required. Contingency funds are included to ensure performance capabilities are met, given that many warranties are not likely to be performance based or be otherwise limited contractually with the shipyard. The ship may be unable to meet the low exhaust gas emissions requirements for the budgeted amount, in which case contingency funds are included to meet emergent regulatory requirements on stack emissions. It is possible a selected shipyard could fail during the construction phase, in which case contingency is included to facilitate transfer to another shipyard. A science prioritized, time-phased de-scoping plan is in place (per NSF policy) to minimize the impact to science capabilities in the case contingency is insufficient to cover realized risks.

Future Operations Costs

Annual ship operations costs are well understood after several decades of experience with vessels of all types in the U.S Academic Research Fleet. OSU understands how to estimate future costs given their experience operating vessels similar to RCRV, such as R/V *Wecoma* and R/V *Oceanus*. OSU included an estimate for the first year of operations using reasonable assumptions for escalations through 2020. They also assumed a robust but reasonable operating schedule of 200 days per year. OSU estimates RCRV will cost $5.0 million to operate in its first year, resulting in a rate of $25,000 per day. This is comparable to the operation of current similar vessels after applying the appropriate cost escalation factors. NSF supports approximately 70 percent of the utilization of the U.S. Academic Research Fleet, which suggests RCRV is likely to cost NSF $3.50 million in the first year. NSF intends to issue a solicitation for an operator of the second RCRV after construction funds are appropriated and will make an award after a competition is held.

Artist's rendition of the RCRV as constructed. *Credit: The Glosten Associates Inc.*

ORGANIZATIONAL EXCELLENCE $541,530,000
+$63,990,000 / 13.4%

Organizational Excellence Funding Summary
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$448.83	$477.54	$541.53	$63.99	13.4%

NSF's Strategic Plan for 2014-2018, *Investing in Science, Engineering, and Education for the Nation's Future*,[1] (released in March 2014) includes "Organizational Excellence" as an NSF core value. The plan defines Organizational Excellence as "investing the resources entrusted to us optimally and efficiently, and realizing the full potential of our people in managing a capable, motivated, inclusive, and positive work environment" – and directly links it to the new strategic goal of "Excel as a Federal Science Agency."

The portfolio of activities included in Organizational Excellence addresses the agency's operations and administrative functions, which underpin NSF's programmatic activities. These activities are critical to the accomplishment of the agency's other two strategic goals, "Transform the Frontiers of Science and Engineering" and "Stimulate Innovation and Address Societal Needs through Research and Education."

NSF's FY 2017 funding for Organizational Excellence is $541.53 million, +$63.99 million, or 13.4 percent, above the FY 2016 Estimate of $477.54 million.

An overview of the various activities that are included in the Organizational Excellence portfolio is included in this summary. The table on the following page shows the major components of Organizational Excellence: Human Capital, Travel, Information Technology (IT), Administrative Support, NSF Headquarters Relocation, and support for the National Science Board (NSB) and the Office of Inspector General (OIG). This table also shows the funding sources for the major components and activities as several are funded through more than one appropriation.

Underlying the FY 2017 Request is NSF's ongoing commitment to increase agency efficiency while constraining administrative costs. NSF has made significant progress toward reducing certain administrative costs by identifying and implementing efficiencies, prioritizing work, eliminating or scaling back the scope of some activities, and by exploring new ways of getting the job done. Examples include investments in business intelligence and other tools that reduce the cost of contract support; and reduced costs associated with maintenance and support of the NSF website due to retirement of dated infrastructure and the conversion of content to modern platforms.

Annually NSF conducts Strategic Reviews of the objectives in the Strategic Plan in response to the requirement of the GPRA Modernization Act. In FY 2015, NSF identified opportunities for action or improvement closely aligned with the Organizational Excellence portfolio of activities.

There were two recommendations that resulted from the Strategic Review of the objective to "Build an increasingly diverse, engaged, and high performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital." These recommendations, which focus on the recruitment and retention of program directors, are: 1) implement regular exit and stay interviews; and 2) develop mechanisms to better manage individual workload and minimize disparities in workload. The

[1] www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14043

Strategic Review of the objective to "Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission" recommended that NSF use the results of the upcoming customer service survey to develop and pilot new customer service goals.

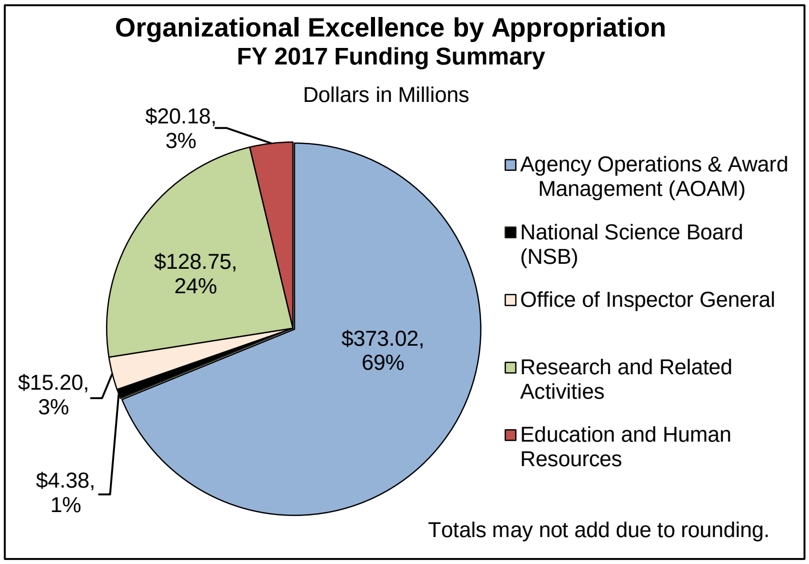
NSF also has performance goals aligned with the Organizational Excellence portfolio of activities: Goal 5: Evidence-Based Management led by the Office of Information and Resource Management and Goal 7: Diversity and Inclusion led by the Office of Diversity and Inclusion in the Office of the Director. More detail on the Strategic Reviews and NSF's performance goals can be found in the Performance chapter.

In FY 2017, NSF continues two key investments in efficiency: 1) Proposal Management Efficiencies (PME), which prioritizes improvements to the agency's systems and processes for managing the merit review of proposals; and 2) Evaluation and Assessment Capability (EAC), which enhances the agency's capability to operate from a basis of evidence in policy decisions. More information on PME and EAC can be found in the NSF-Wide Investments chapter.

An overview of the various activities that are included in the Organizational Excellence portfolio follows. Also included in this discussion is information on the E-Government Initiatives to which the agency contributes.

Organization Excellence by Appropriation

Organizational Excellence funding by account for the FY 2017 Budget Request is shown in the chart on the right and in the table below.



- Sixty-nine percent of Organizational Excellence is funded through AOAM.
- The R&RA account funds program support costs of $128.75 million (24 percent) and the EHR account funds program support costs of $20.18 million (three percent).
- The activities of the OIG and NSB are each funded by separate appropriation accounts. The FY 2017 Budget Request for the OIG of $15.20 million accounts for three percent of the Organizational Excellence portfolio. The NSB FY 2017 Budget Request of $4.38 million accounts for one percent of the Organizational Excellence portfolio.

Organizational Excellence by Appropriation

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Agency Operations & Award Management (AOAM)	$306.56	$330.00	$373.02	$43.02	13.0%
National Science Board (NSB)	4.15	4.37	4.38	0.01	0.2%
Office of Inspector General (OIG)	14.60	15.16	15.20	0.04	0.3%
Program Support:					
Research and Related Activities	107.30	110.74	128.75	18.01	16.3%
Education and Human Resources	16.21	17.28	20.18	2.90	16.8%
Subtotal, Program Support	*$123.52*	*$128.01*	*$148.94*	*$20.93*	*16.4%*
Total	**$448.83**	**$477.54**	**$541.53**	**$63.99**	**13.4%**

Total may not add due to rounding.

Organizational Excellence by Major Component

The table below shows the major components of Organizational Excellence: Human Capital, Travel, Information Technology (IT), Administrative Support, NSF Headquarters Relocation, and support for the National Science Board (NSB) and the Office of Inspector General (OIG). This table also shows the funding sources for the major components/activities, as several are funded through more than one appropriation.

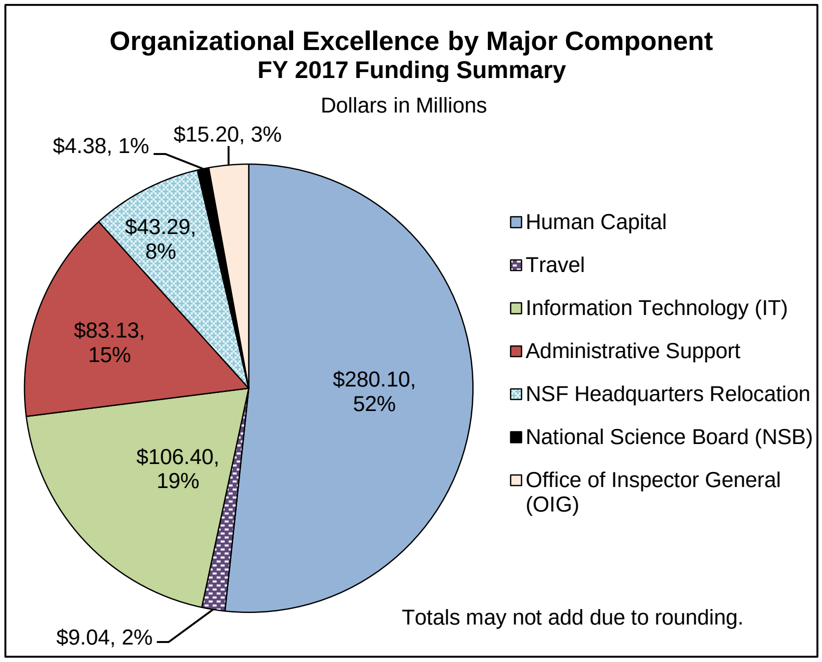
Organizational Excellence by Major Component
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent	Funding Source
Human Capital	$249.58	$271.04	$280.10	$9.06	3.3%	
Personnel Compensation & Benefits[1]	199.63	215.53	219.55	4.02	1.9%	AOAM
Management of Human Capital	8.08	10.00	10.20	0.20	2.0%	AOAM
IPA Appointments	41.87	45.51	50.35	4.84	10.6%	
Compensation	37.97	41.16	45.50	4.34	10.5%	RRA/EHR
Lost Consultant & Per Diem	3.90	4.36	4.85	0.49	11.2%	RRA/EHR
Travel	$8.65	$8.87	$9.04	$0.17	1.9%	
NSF Federal Employee Staff	5.51	5.45	5.45	-	-	AOAM
IPA Appointments	3.14	3.42	3.59	0.17	5.0%	RRA/EHR
Information Technology (IT)	$95.17	$85.39	$106.40	$21.01	24.6%	
Agency Operations IT	27.18	21.99	25.60	3.61	16.4%	
Administrative Applications Services and Support	6.86	5.11	6.73	1.62	31.7%	AOAM
Administrative IT Operations and Infrastructure	17.53	13.84	15.84	2.00	14.5%	AOAM
Administrative Security and Privacy Services	2.79	3.03	3.03	-	-	AOAM
Program Related Technology (PRT)	67.99	63.40	80.80	17.40	27.4%	
Mission-Related Applications and Services	51.15	45.99	56.99	11.00	23.9%	RRA/EHR
Mission-Related IT Operations and Infrastructure	13.90	14.44	19.84	5.40	37.4%	RRA/EHR
Mission-Related Security and Privacy Services	2.94	2.98	3.98	1.00	33.6%	RRA/EHR
Administrative Support	$73.98	$83.78	$83.13	-$0.65	-0.8%	
Space Rental	34.00	34.17	32.44	-1.73	-5.1%	AOAM
Operating Expenses	15.78	20.86	22.40	1.54	7.4%	AOAM
Building and Administrative Services	13.69	13.07	14.09	1.02	7.8%	AOAM
Other Program Related Administration	10.51	15.68	14.20	-1.48	-9.4%	
Evaluation and Assessment Capability	6.84	8.86	8.86	-	-	RRA/EHR
Proposal Management Efficiencies	0.35	0.34	0.38	0.04	11.8%	RRA/EHR
E-Government Initiatives	1.01	1.01	1.44	0.43	42.6%	RRA/EHR
General Planning and Evaluation Activities	2.31	5.47	3.52	-1.95	-35.6%	RRA/EHR
NSF Headquarters Relocation	$2.70	$8.93	$43.29	$34.36	384.8%	AOAM
National Science Board (NSB)	$4.15	$4.37	$4.38	$0.01	0.2%	NSB
Office of Inspector General (OIG)	$14.60	$15.16	$15.20	$0.04	0.3%	OIG
Total, Organizational Excellence	**$448.83**	**$477.54**	**$541.53**	**$63.99**	**13.4%**	

Totals may not add due to rounding.

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2015, $5.98 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $205.61 million. Approximately $5.82 million in ACRs are expected each year to meet the total PC&B requirement of $221.35 million in FY 2016 and $225.37 million in FY 2017.

The chart on the right shows the major components of Organizational Excellence and their percentage of the total in the FY 2017 Budget Request.



1. Human Capital: The FY 2017 funding amount for Human Capital is $280.10 million, an increase of $9.06 million, or 3.3 percent, over the FY 2016 Estimate of $271.04 million. Support for NSF's human capital activities is the largest component of Organizational Excellence, accounting for 52 percent of the total portfolio. The Human Capital component includes personnel compensation and benefits of NSF's federal employees as well as support for NSF's temporary employees hired through authority provided by the Intergovernmental Personnel Act, known as "IPAs." NSF's federal employee FTE (full-time equivalents) are funded through the Agency Operations and Award Management (AOAM) account while IPAs are funded through two programmatic accounts – Research and Related Activities (R&RA) and Education and Human Resources (EHR). The use of IPAs and Visiting Scientists, Engineers, and Educators (VSEEs, also funded out of AOAM), together commonly referred to as rotators, has been a defining characteristic of NSF since its inception in 1950, as it gives NSF a direct connection to the researchers and educators working at the frontiers of science and engineering.

The Human Capital component also includes support for the Management of Human Capital, which includes:

- Human resources systems accessed through shared service providers, including the Federal Personnel Payroll System, the time and attendance system (WebTA), eRecruit capabilities using USAJobs, and security investigations of incoming staff.
- Operational activities including recruiting, hiring, and on-boarding of permanent and rotating staff, as well as processing support for pay and benefits and awards.
- Workplace and career-life balance support for employees including the Health Unit, the Employee Assistance Program, and child care subsidy.
- Contracts that support training and development programs, on-line training capabilities, networking activities including the NSF mentoring program, executive and supervisory training, and program management training.

NSF Workforce:
The table below shows the agency's total workforce for FY 2017.

NSF Workforce

Full-Time Equivalents (FTE)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
AOAM FTE Allocation					
Regular	*1,310*	*1,310*	*1,310*	-	-
Pathways Interns [1]	*42*	*42*	*42*	-	-
Subtotal, AOAM FTE Allocation	*1,352*	*1,352*	*1,352*	-	-
AOAM FTE Usage (Actual/Projected)					
Regular	1,255	1,310	1,310	-	-
Pathways Interns [1]	30	42	42	-	-
Subtotal, AOAM FTE	1,285	1,352	1,352	-	-
Office of the Inspector General	68	75	68	-7	-9.3%
Regular	68	75	68	-7	-9.3%
National Science Board	18	19	19	-	-
Arctic Research Commission	3	3	3	-	-
Total, Federal Employees (FTE)	1,374	1,449	1,442	-7	-0.5%
IPAs (FTE)	171	189	202	13	6.9%
Detailees to NSF	3	3	3	-	-
Contractors (est.)	449	449	449	-	-
Total, Workforce	**1,997**	**2,090**	**2,096**	**6**	**0.3%**

Totals may not add due to rounding.

[1] The Pathways Intern program was established by Executive Order 13562, Recruiting and Hiring Students and Recent Graduates. The internship program offers part- or full-time paid internships in federal agencies to qualifying students (students in high schools, community colleges, four-year colleges, trade schools, career and technical education programs, and other qualifying technical education programs).

- NSF's FTE allocation and utilization for FY 2017 are held flat with the FY 2016 Estimate of 1,310 FTE.
- A number of visiting staff – roughly 40 people annually – are employed through NSF's own Visiting Scientist, Engineer, and Educator (VSEE) program. VSEEs count as regular federal FTE and are included in the regular AOAM FTE totals.

A discussion of NSF's FTE allocation and usage is included in the Personnel Compensation and Benefits section of the AOAM chapter. A more detailed discussion about IPAs is included in the Program Accounts: R&RA and EHR chapter. The OIG, NSB, and Arctic Research Commission chapters include a discussion of their respective workforces.

2. Travel: Support for NSF staff and IPA travel accounts for two percent of NSF's Organization Excellence portfolio. For FY 2017, the request for staff and IPA travel is $9.04 million, $170,000 above the FY 2016 Estimate of $8.87 million. Staff travel accounts for about 60 percent of this total; a request of $5.45 million in FY 2017. Travel for IPA appointments, which is supported by the R&RA and EHR accounts, is $3.59 million. For more detailed information about NSF staff and IPA travel funding, see the

AOAM and Program Accounts: R&RA and EHR chapters, respectively. Based on current trends, AOAM funded travel is estimated to account for approximately 25 percent of NSF's FY 2017 total travel estimated cost.

3. Information Technology (IT): IT investments are the second largest component of Organizational Excellence, accounting for 19 percent of the portfolio. For FY 2017, IT investments total $106.40 million, a $21.01 million, or 24.6 percent, increase above the FY 2016 Estimate of $85.39 million. The increase in FY 2017 supports the following information technology priorities:

- +$7.40 million to support the expansion of infrastructure capabilities that support the modernization of mission-centric merit review systems and processes. Additionally, this increase allows for the preparation of NSF's IT systems for relocation to the new NSF headquarters, enables parallel infrastructures to be run during the relocation, as services and staff are transitioned from the current headquarters to the new location, and further increases the security of NSF's infrastructure in response to the ever-evolving threat landscape.
- +$5.56 million for NSF's Enterprise Data Warehouse, a centralized data repository that streamlines access to NSF data for NSF staff and provides analysis capabilities that inform NSF portfolio management, evaluation, and assessment. The requested increase will allow NSF to move more NSF data sets into the warehouse, implement additional reporting tools, and support requirements of the Digital Accountability and Transparency (DATA) Act.
- +$2.0 million to modernize NSF.gov and support NSF efforts to provide the general public with high quality digital information and services.
- +$2.05 million for iTRAK, NSF's financial management system, to fund high priority change requests, implement electronic invoicing, and support requirements of the DATA Act.
- +$1.0 million for administrative applications services to make high priority changes to administrative systems to ensure the continued effective operation of NSF's legacy property and procurement applications, and upgrade to the current version of SharePoint to ensure continued operation of collaboration sites and their continued interoperability with NSF's desktop services.
- +$1.0 million for security and privacy services to enhance continuous monitoring capabilities, reduce NSF's cybersecurity vulnerabilities, and better position NSF to respond to cybersecurity threats.
- +$1.30 million to support legacy mission related applications and ensure they change apace with changes to iTRAK.
- +$700,000 for Proposal Management Efficiencies (PME) to continue the modernization of applications and services that support the merit review process, including services to increase automated compliance checking of NSF proposals and to upgrade proposal submission services.

Funding for NSF's IT investment is provided from Agency Operations and Award Management (AOAM), the Research and Related Activities (R&RA), and Education and Human Resources (EHR) accounts.

IT Investments by Appropriation
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Request Amount	Change over FY 2016 Request Percent
Agency Operations & Award Management (AOAM)	$27.18	$21.99	$25.60	$3.61	16.4%
Program Related Technology (PRT)	$67.99	$63.40	$80.80	$17.40	27.4%
Research and Related Activities (R&RA)	57.47	55.16	70.30	15.14	27.4%
Education and Human Resources (EHR)	10.53	8.24	10.50	2.26	27.4%
Total	**$95.17**	**$85.39**	**$106.40**	**$21.01**	**24.6%**

Totals may not add due to rounding.

- Agency operations IT investments funded through the AOAM account support the agency's operations to ensure high quality, reliable, and secure administrative applications and associated IT infrastructure support and services to meet the needs of the Foundation. This funding accounts for about 24 percent of NSF's total IT investment in the FY 2017 Budget Request. Additional detail regarding the AOAM funded IT investments can be found in the AOAM chapter.

- Program Related Technology (PRT) investments support NSF's programmatic activities and associated services and are funded through the R&RA and EHR accounts. PRT investments are mission-related IT investments that support the merit review process, including pre-award planning and activities; receipt of proposals; processing proposals; reviewing proposals; award decisions, documentation, and notification; funding awards; post-award oversight; dissemination of award results; and award close-out. PRT investments account for 76 percent of NSF's FY 2017 Request for IT investments. More information on PRT can be found in the Program Accounts: R&RA and EHR chapter.

4. Administrative Support: Funding for Administrative Support accounts for 15 percent of the total Organizational Excellence portfolio in FY 2017. FY 2017 funding for Administrative Support is $83.13 million, a $650,000 (0.8 percent) decrease below the FY 2016 Estimate of $83.78 million. Included in this amount are funds for agency implementation of sustainability goals outlined in NSF's Strategic Sustainability Performance Plan, in association with meeting the goals of E.O. 13693. The activities that comprise Administrative Support are detailed below.

- The largest component of Administrative Support is Space Rental at $32.44 million – a decrease of $1.73 million below the FY 2016 Estimate of $34.17 million. Space rental includes services provided by the General Services Administration related to rent, utilities, taxes, and security services provided by the Federal Protective Service. NSF currently occupies 665,000 square feet of space primarily in two adjoining, leased office buildings located in Arlington, Virginia. The current leases for the two buildings have been replaced by interim occupancy agreements that extend occupancy until the upcoming move of NSF to Alexandria, Virginia. The FY 2017 Budget Request includes 12 months of rent at the Arlington location and one month of rent at the Alexandria location. More detailed information about Space Rental can be found in the AOAM chapter.
- Operating Expenses (+$1.54 million to a total of $22.40 million) include funding for supplies and equipment, training, communications devices, and printing, which are necessary for the accomplishment of NSF's mission. In addition, various financial and award management and leadership activities are supported, such as post-award monitoring; contract close-out activities; large facility oversight; improper payments, financial statement, and internal controls reporting; CEOSE (Committee on Equal Opportunities in Science and Engineering) activities; and the Enterprise Information System. A detailed discussion about Operating Expenses can be found in the AOAM chapter.
- Building and Administrative Services (+$1.02 million to a total of $14.09 million) includes administrative contracts that support NSF's facilities and business operations such as the mail center, loading dock, supply and warehouse management; conference room and merit review panel support including audiovisual and virtual meeting support; printing, digital scanning and imaging; travel management support; NSF intranet operations and maintenance; and the visitor information center. Funding for administrative services, equipment, and supplies support NSF's infrastructure and include activities such as security system maintenance, ID issuance, public announcement system maintenance, the NSF Alert System, continuity of operations support services, and Federal Register notices for panels and advisory committees. Funding for government goods and services include support of core business activities such as records storage and relocation administration. A detailed discussion of these activities can be found in the AOAM chapter.
- Other Program Related Administration (PRA) decreases $1.48 million to a total of $14.20 million to support general Planning and Evaluation activities, which are agency-wide efforts such as the

verification and validation of performance information; certain IPA costs; some American Association for the Advancement of Science (AAAS) fellowships costs, and E-Government efforts. Ongoing support also is provided for two management improvement efforts—Evaluation and Assessment Capability (EAC) and Proposal Management Efficiencies (PME). Detailed information about both EAC and PME can be found in the NSF-Wide Priorities chapter. A detailed discussion about Other PRA can be found in the Program Accounts: R&RA and EHR chapter.

5. NSF Headquarters (HQ) Relocation: In June 2013, GSA awarded a 15-year lease for NSF's new headquarters to be located in Alexandria, Virginia. The FY 2017 Request is for $43.29 million, and is about eight percent of the Organizational Excellence portfolio. This provides support for HQ Relocation program management costs, technology costs, furniture, fixture, and equipment costs, and move costs to relocate NSF staff, furniture, equipment, and other materials to the new location. More detailed information about NSF HQ Relocation can be found in the AOAM chapter.

6. National Science Board (NSB): The staffing and operations of the NSB office are supported through a separate NSB appropriation representing one percent of the Organizational Excellence portfolio. Details about the NSB FY 2017 Budget Request can be found in the NSB chapter.

7. Office of Inspector General (OIG): The staffing and operations of the OIG are supported through a separate OIG appropriation representing three percent of the Organizational Excellence portfolio. Details about the OIG FY 2017 Budget Request can be found in the OIG chapter.

NSF FY 2016 Estimate and FY 2017 Request Submission Funding for E-Government Initiatives

The tables below show NSF's contributions and service fees for various E-Government initiatives. The FY 2017 Budget Request is increased $441,246 above the FY 2016 Estimate. This level is consistent with the FY 2017 funding amounts provided by the initiatives' respective managing partners and reflects funding level changes for the following initiatives:

- Grants.gov changed its agency charging algorithm for FY 2017, decreasing NSF’s service fee by approximately $172,238;
- E-Rulemaking increases $3,986;
- The Integrated Award Environment (IAE) initiative changed its agency charging algorithm for FY 2017, increasing NSF’s service fee for IAE- loans and grants by $603,666; and
- NSF’s contribution to the Budget Formulation and Execution Line of Business increases $5,000.

NSF FY 2016 Estimate Funding for E-Government Initiatives

	FY 2016			Appropriations Account	
Initiative	Agency Contributions	Agency Svc. Fees	NSF Total	AOAM	R&RA
Grants.gov	$435,517	-	$435,517	-	$435,517
E-Travel	-	184,467	184,467	184,467	
Geospatial LoB	25,000	-	25,000	-	25,000
E-Training	-	370,000	370,000	370,000	-
E-Rulemaking	-	10,374	10,374	10,374	-
USA Jobs	-	8,342	8,342	8,342	-
E-Human Resource Integration	-	24,634	24,634	24,634	-
Integrated Acquisition Environment (IAE) including Loans and Grants	-	253,544	253,544	18,079	235,465
Human Resources Management LoB	65,217	-	65,217	-	65,217
Financial Management LoB	139,094	-	139,094	-	139,094
Budget Formulation/Execution LoB	105,000	-	105,000	-	105,000
E-Payroll (incl. Shared Services)	-	314,640	314,640	314,640	-
Total	**$769,828**	**$1,166,001**	**$1,935,829**	**$930,536**	**$1,005,293**

LoB: Line of Business; Totals may not add due to rounding.

NSF FY 2017 Request Funding for E-Government Initiatives

	FY 2017			Appropriations Account	
Initiative	Agency Contributions	Agency Svc. Fees	NSF Total	AOAM	R&RA
Grants.gov	$263,279	-	$263,279	-	$263,279
E-Travel	-	184,467	184,467	184,467	-
Geospatial LoB	25,000	-	25,000	-	25,000
E-Training	-	370,000	370,000	370,000	-
E-Rulemaking	-	14,360	14,360	14,360	-
USA Jobs	-	9,174	9,174	9,174	-
E-Human Resource Integration	-	24,634	24,634	24,634	-
Integrated Acquisition Environment (IAE) including Loans and Grants	-	857,210	857,210	21,000	836,210
Human Resources Management LoB	65,217	-	65,217	-	65,217
Financial Management LoB	139,094	-	139,094	-	139,094
Budget Formulation/Execution LoB	110,000	-	110,000	-	110,000
E-Payroll (incl. Shared Services)	-	314,640	314,640	314,640	-
Total	**$602,590**	**$1,774,485**	**$2,377,075**	**$938,275**	**$1,438,800**

LoB: Line of Business; Totals may not add due to rounding.

PROGRAM ACCOUNTS: R&RA and EHR $148,940,000 +$20,930,000 / 16.4%

Funding from program accounts (R&RA and EHR) covers approximately 27 percent of the total Organizational Excellence portfolio. Two activities comprise program-funded Organizational Excellence: Intergovernmental Personnel Act (IPA) costs and Program Related Administration.

Summary of R&RA- and EHR-Funded Organizational Excellence
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate: Amount	Percent
IPA Costs	**$45.01**	**$48.93**	**$53.94**	**$5.01**	**10.2%**
IPA Compensation	37.97	41.16	45.50	4.34	10.5%
IPA Lost Consultant & Per Diem	3.90	4.36	4.85	0.49	11.2%
IPA Travel	3.14	3.42	3.59	0.17	5.0%
Program Related Administration	**$78.51**	**$79.08**	**$95.00**	**$15.92**	**20.1%**
Program Related Technology	67.99	63.40	80.80	17.40	27.4%
Other Program Related Administration	10.51	15.68	14.20	-1.48	-9.4%
Total, R&RA and EHR Funded Organizational Excellence	**$123.52**	**$128.01**	**$148.94**	**$20.93**	**16.4%**

Totals may not add due to rounding.

Intergovernmental Personnel Act (IPA) Costs

A portion of NSF's workforce consists of temporary staff hired through the Intergovernmental Personnel Act (IPA) authority. IPAs remain employees of their home institution while serving at NSF during their temporary appointment. They are not paid directly by NSF and are not subject to federal pay, benefits, or other limitations. NSF reimburses their home institution without overhead using the traditional grant mechanism. IPAs are eligible to receive relocation expenses, or a per diem allowance in lieu of relocation, and reimbursement for income foregone because of their assignment at NSF (i.e., lost consulting fees).

The agency uses IPA science and engineering staff to help ensure that the Foundation's funding decisions are based on the best input from the field, and reflect fresh ideas and creativity. The expertise provided by these IPAs is essential to help shape the NSF research portfolio and support transformational advances across the frontiers of all fields of science, engineering, and education.

IPA Costs by Appropriation

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
IPA FTE Utilization[1]	171	183	196	13	7.1%
Research and Related Activities (R&RA)					
IPA Compensation	$33.25	$35.46	39.27	$3.81	10.7%
IPA Lost Consultant & Per Diem	3.31	3.67	4.07	0.40	10.9%
Travel	2.81	2.99	3.15	0.16	5.4%
Subtotal, R&RA Costs	**$39.37**	**$42.12**	**$46.49**	**$4.37**	**10.4%**
Education and Human Resources (EHR)					
IPA Compensation	4.72	5.70	6.23	0.53	9.3%
IPA Lost Consultant & Per Diem	0.59	0.69	0.78	0.09	13.0%
Travel	0.33	0.43	0.44	0.01	2.3%
Subtotal, EHR Costs	**$5.64**	**$6.82**	**$7.45**	**$0.63**	**9.2%**
Total, IPA Costs[1]	**$45.01**	**$48.93**	**$53.94**	**$5.01**	**10.2%**

Totals may not add due to rounding.

[1] The FY 2015 Actual FTE utilization and total obligations reflect the costs associated with six IPAs in staff offices (BFA, OIRM, and OLPA). These six IPAs are not included in this table for FY 2016 and FY 2017. Approximately $1.50 million in FY 2016 and FY 2017 for these six IPAs is budgeted within Other Program Administration and included in the General Program and Evaluation (P&E) activities section of the this narrative.

FY 2017 Request funding of $53.94 million for IPA costs represents an increase of $5.01 million, or 10.2 percent, over the FY 2016 Estimate of $48.93 million. The FY 2017 Request IPA usage level of 196 FTE is 13 FTE, or 7.1 percent, greater than the FY 2016 Estimate; R&RA IPA FTE increases by ten and EHR IPA FTE increases by three.

R&RA funding for IPAs increases $4.37 million over the FY 2016 Estimate. Roughly 64 percent of this increase ($2.79 million) is related to the increase of ten FTEs. The remaining $1.58 million (30 percent) reflects an increase in per IPA costs related to compensation and lost consultant and per diem. The increase in per IPA costs were determined based on the FY 2015 Actual obligations for IPAs and market forces impacting the organizations where the bulk of the increases in IPAs and largest numbers of IPAs are found.

EHR funding for IPAs increases $630,000 over the FY 2016 Estimate reflecting the proposed increase of three FTEs. EHR's cost per FTE are held flat with the FY 2016 Estimate.

IPA compensation increases by $4.34 million, or 10.5 percent, above the FY 2016 Estimate to a total of $45.50 million. Lost consultant and per diem is funded at $4.85 million, +$490,000, or 11.2 percent, over the FY 2016 Estimate. FY 2017 Request funding for IPA travel is $3.59 million, +$170,000, or 5.0 percent, above the FY 2016 Estimate. Funding for these three categories is associated with full use of NSF's existing IPA FTE allocation and projected IPA costs for FY 2017.

Program Related Administration

Program Related Administration Investments

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Program Related Technology	$67.99	$63.40	$80.80	$17.40	27.4%
Other Program Related Administration	10.51	15.68	14.20	-1.48	-9.4%
Total, Program Related Administration	**$78.50**	**$79.08**	**$95.00**	**$15.92**	**20.1%**

Totals may not add due to rounding.

Program Related Administration (PRA) increases $15.92 million above the FY 2016 Estimate to $95.0 million for the FY 2017 Request. It includes two categories of activities that support NSF's strategic goal, Excel as a Federal Science Agency, and that are directly funded from NSF's program accounts:

- Program Related Technology (PRT); and
- Other Program Related Administration (Other PRA)

The FY 2017 increase for PRA is driven by the increased needs and requirements in PRT.

Program Related Technology (+$17.40 million, to a total of $80.80 million)
NSF requests a FY 2017 information technology (IT) investment of $106.40 million. The portion of NSF's IT investment funded through the R&RA and EHR accounts supports NSF's mission activities and account for approximately 76 percent of NSF's IT investment portfolio. The FY 2017 PRT funding request is $80.80 million, an increase of $17.40 million above the FY 2016 Estimate. The remaining $25.60 million IT investment is AOAM funded and is discussed in the AOAM chapter.

Program Related Technology Investments

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Mission-Related Applications and Services	$51.15	$45.99	$56.99	$11.00	23.9%
Mission-Related IT Operations and Infrastructure	13.90	14.44	19.84	5.40	37.4%
Mission-Related Security and Privacy Services	2.94	2.98	3.98	1.00	33.6%
Total, Program Related Technology	**$67.99**	**$63.40**	**$80.80**	**$17.40**	**27.4%**

Totals may not add due to rounding.

NSF accomplishes its mission through federal financial assistance to individuals and institutions whose proposals have been judged the most promising by a rigorous and objective review process. Each stage in the NSF proposal and award management process is supported electronically. The IT services and systems that support the proposal and review process are funded through the PRT investment, an essential element in our Nation's support for science, engineering, and education research.

For FY 2017, NSF's information technology priorities for PRT are:

- Implementing electronic invoicing. NSF is exploring options and may use a shared service provider to implement in FY 2017. This activity would support the Shared Services cross-agency priority goal

(CAP): to strategically expand high-quality, high value shared services to improve performance and efficiency throughout government.[1]

- Enhance the security of NSF's infrastructure to respond to the ever evolving threat landscape and strengthen continuous monitoring capabilities and better posture NSF to respond to cybersecurity vulnerabilities. This supports the Cybersecurity CAP goal: improve cybersecurity performance through ongoing awareness of information security, vulnerabilities, and threats impacting the operating information environment, ensuring that only authorized users have access to resources and information; and the implementation of technologies and processes that reduce the risk of malware.[2]
- Expand NSF's Enterprise Data Warehouse to include more data sets and additional reporting tools to strengthen NSF's use of data and evidence to drive better decision-making and achieve greater impact.
- Continue to work toward a federated system to manage results of NSF-funded research that integrates external (repository) and internal administrative systems with minimal additional burden to NSF awardees and staff.
- Modernize NSF.gov, leveraging best practices from the U.S. Digital Service Team where possible, to make it easier to update information and provide the general public and the science and engineering research and education communities with access to high quality digital government information and services.
- Support the continued operation of iTRAK, the Foundation's financial management system and make changes to iTRAK to support the requirements of the Digital Accountability and Transparency (DATA) Act.
- Ensure legacy mission systems change apace as changes are made to iTRAK.
- Continue modernization of systems that support the merit review process in order to reduce administrative burden to researchers and NSF staff. Focus will be on systems that support the management of proposals, reviews, and reviewers and the expansion of infrastructure capabilities to support these modernizations.
- Prepare IT systems for transfer to the new NSF headquarters.
- Operation of parallel infrastructures during the relocation to the new NSF headquarters; this is required to ensure business continuity during the transition.

Mission-Related Applications and Services (+$11.0 million, to a total of $56.99 million)
Investments in this category fund the applications and services that support the merit review process, including pre-proposal planning; receipt of proposals; processing proposals; reviewing proposals; award decisions, documentation, and notification; funding awards; post-award oversight; dissemination of award results; and award close-out. Mission-related applications and services include investments such as iTRAK, Research.gov, eJacket, and FastLane.

- iTRAK is NSF's financial management system. The total FY 2017 investment for iTRAK is $7.75 million. Seventy percent of this request is funded by PRT and 30 percent is funded by AOAM. The PRT portion of the iTRAK request increases by $1.44 million to a total of $5.43 million, to support high priority enhancements, to implement electronic invoicing, a potential new shared service planned for FY 2017, and to support the requirements of the DATA Act.
- Legacy Mission Applications, +$3.65 million to a total of $32.10 million, supports several different mission-related activities:
  - Other Mission Applications, +$3.65 million to a total of $18.47 million in FY 2017 to fund the following projects:
    - +$1.30 million to ensure legacy mission applications change apace with changes to iTRAK.
    - +$350,000 to continue the modernization of the legacy mission applications that support the merit review process and the Proposal Management Efficiencies (PME) initiative. As part of

[1] www.performance.gov/node/3398/view?view=public#overview
[2] www.performance.gov/node/3401/view?view=public#overview

these modernization efforts, NSF will look for opportunities to improve agency digital services and information, leveraging best practices from the U.S. Digital Service Team where possible.
    - +$2.0 million to modernize NSF.gov, which is the primary locus of public information about NSF and NSF funding opportunities. The requested amount will support NSF efforts to provide the general public with high quality digital information and services.
  - Public Access Initiative, plus zero to a total of $3.0 million, increases public access to the results of NSF-funded research. Specifically, the requested funds will be used to maintain the NSF Public Access Repository by: integrating it with internal award management systems; initiating planning activities to expand NSF's federated model for public access to additional repositories; and enhancing the services provided to users of NSF's public access capability.
  - eJacket, plus zero to a total of $5.72 million, provides the necessary funds for operations and maintenance of this mission support system.
  - FastLane, plus zero to a total of $4.91 million, provides the necessary funds for operations and maintenance of this mission support system.
- Research.gov, +$350,000 to a total of $10.65 million, is a community driven solution led by NSF that gives the science and engineering research and education communities and the public easy access to key information and services in one location (www.research.gov). Research.gov also provides services to help NSF staff plan and manage their programs and proposal and award portfolios. The requested increase will fund continued modernization of services, as part of PME, that support the merit review process, including services to increase automated compliance checking of NSF proposals and to upgrade proposal submission services. As part of these modernization efforts, NSF will look for opportunities to improve digital information and services.
- NSF's Enterprise Data Warehouse, +$5.56 million to a total of $8.06 million, centralizes and streamlines access to NSF data for NSF staff. The analysis capabilities provided by the Enterprise Data Warehouse and related tools inform NSF portfolio management, evaluation, and assessment. The requested increase will allow NSF to move more NSF data sets into the warehouse, implement additional reporting tools, and support the requirement of the DATA Act.
- Enterprise architecture and planning, plus zero to a total of $754,000, is consistent with the FY 2016 Estimate.

Mission-Related IT Operations and Infrastructure (+$5.40 million, to a total of $19.84 million)
Investments in this category provide basic operations and maintenance funding for NSF infrastructure, network, and telecommunications requirements. Network services include NSF's primary network for NSF staff, an external network for NSF visitors, and connection to Internet2 for virtual meeting support. Additionally, this category includes NSF's help desk services for internal users (NSF staff) and external users (the research community including institutions, principal investigators, reviewers, and other NSF visitors) 13 hours per day, five days per week.

The $5.40 million increase will allow for the expansion of infrastructure capabilities that support the modernization of merit review systems. Additionally, this investment will prepare IT systems for relocation to the new NSF headquarters and fund parallel infrastructures during the relocation, essential for ongoing operations during the transition. The requested amount will also increase the security of NSF's infrastructure.

Mission-Related Security and Privacy Services (+$1.0 million, to a total of $3.98 million)
Investments in this category include automated configuration management tools that manage security patches and provide proactive protection from viruses, spyware, and other threats. This investment covers the mission-related portion of NSF's network security, application security, security control testing and tools, automated vulnerability assessment tools, and remediation and intrusion detection services.

The $1.0 million increase will be used to enhance continuous monitoring capabilities, reduce NSF's cybersecurity vulnerabilities, and better position NSF to respond to cybersecurity threats.

<u>Other Program Related Administration (-$1.48 million, to a total of $14.20 million)</u>
In FY 2017, NSF's Other PRA includes funding for four Foundation-wide activities:

- Evaluation and Assessment Capability (EAC);
- Proposal Management Efficiencies (PME);
- NSF support for federal E-Government initiatives that are mission-related; and
- General planning and evaluation (P&E) activities that are Foundation-wide.

Other Program Related Administration
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Proposal Management Efficiencies	$0.35	$0.34	$0.38	$0.04	11.8%
Evaluation and Assessment Capabilities	6.84	8.86	8.86	-	-
E-Government Initiatives	1.01	1.01	1.44	0.43	42.6%
General Planning and Evaluation Activities	2.31	5.47	3.52	-1.95	-35.6%
Total, Other Program Related	**$10.51**	**$15.68**	**$14.20**	**-$1.48**	**-9.4%**

Totals may not add due to rounding.

Proposal Management Efficiencies (+$40,000, to a total of $380,000)
FY 2017 Other Program Related Administration funding of $380,000 increases support for assessment activities within Proposal Management Efficiencies. These assessment activities provide feedback on the impacts of NSF's investments in improving the merit review process and are used to identify further potential enhancements. More detailed information can be found in the PME narrative in the NSF-Wide Priorities chapter.

Evaluation and Assessment Capability (no change, to a total of $8.86 million)
In FY 2017, Other PRA funding of $8.86 million will enable further development of the Foundation's Evaluation and Assessment Capability. Activities supported include articulating evaluation principles and practices across the foundation through workshops, training programs, and website development for internal and external sharing of NSF evaluation activities; developing and conducting evaluations for cross-cutting, high visibility programs; and implementing a flexible evaluation and assessment framework and building evaluation capacity through data collection, development of evaluation methods, and development of analytical and visualization tools. More detailed information for EAC can be found within the NSF-Wide Priorities chapter.

E-Government Initiatives (+$434,000, to a total of $1.44 million)
The FY 2017 Budget Request for NSF program-supported and mission-related E-Government initiatives is increased $434,000 above the FY 2016 Estimate. This level is consistent with the FY 2017 funding amounts provided by the initiatives' respective managing partners and reflects funding level changes for the following initiatives:

- The Integrated Award Environment (IAE) initiative changed its agency charging algorithm for FY 2017, increasing NSF's service fee for IAE- loans and grants by approximately $600,000;
- NSF's contribution to the Budget Formulation and Execution Line of Business increases $5,000; and
- Grants.gov changed its agency charging algorithm for FY 2017, decreasing NSF's service fee by approximately $172,000.

General Planning and Evaluation Activities (-$1.95 million, to a total of $3.52 million)
FY 2017 Other Program Related Administration funding for general planning and evaluation activities is $3.52 million, which supports activities on broad programmatic and policy matters of NSF-wide scope and benefit. This includes activities such as the verification and validation of performance information; six IPAs in the offices of Budget Finance and Award Management and Resource and Information Management; and certain costs associated with the American Association for the Advancement of Science (AAAS) fellowships program.

Beginning in FY 2016, funding for the Organization for Economic Co-operation and Development funding is provided through the Office of International Science and Engineering. It was previously provide through P&E. In FY 2017, several activities previously funded through P&E – the Vannevar Bush, Public Service, and Waterman awards; the National Medal of Science; the Summer Science Internships Program; and NSF collaborations with the National Academies of Science including the Federal Demonstration Partnership, the Government-University-Industry Research Roundtable, and the Committee on Science, Engineering, and Public Policy – are now included in the Planning and Policy Support line within Integrative Activities.

The FY 2017 funding estimate is based on the level of Other PRA activities and projects that occurred in FY 2015 and anticipated activities for FY 2017.

AGENCY OPERATIONS AND AWARD MANAGEMENT

$373,020,000
+$43,020,000 / 13.0%

Summary of Agency Operations and Award Management
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
Personnel Compensation and Benefits[1]	$199.63	$215.53	$219.55	$4.02	1.9%
Management of Human Capital	8.08	10.00	10.20	0.20	2.0%
Travel	5.51	5.45	5.45	-	-
Information Technology	27.18	21.99	25.60	3.61	16.4%
Space Rental	34.00	34.17	32.44	-1.73	-5.1%
Operating Expenses	15.78	20.86	22.40	1.54	7.4%
Building and Administrative Services	13.69	13.07	14.09	1.02	7.8%
NSF HQ Relocation	2.70	8.93	43.29	34.36	384.8%
Total, AOAM	**$306.56**	**$330.00**	**$373.02**	**$43.02**	**13.0%**

Totals may not add due to rounding.

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2015, $5.98 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $205.61 million. Approximately $5.82 million in ACRs are expected each year to meet the total PC&B requirement of $221.35 million in FY 2016 and $225.37 million in FY 2017.

Investments in the Agency Operations and Award Management (AOAM) account continue to be an NSF priority. This activity provides the fundamental framework through which the Foundation's science and engineering research and education programs are administered.

AOAM investments support NSF Strategic Goal 3: Excel as a Federal Science Agency. AOAM's priorities are framed by two strategic objectives:

- Strategic Objective 1: Build an increasingly diverse, engaged, and high-performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital; and
- Strategic Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

NSF AOAM Workforce

NSF AOAM Workforce
(Full-Time Equivalent (FTE) and Other Staff)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
NSF AOAM FTE Allocation					
NSF AOAM -- Regular	1,310	1,310	1,310	-	-
NSF AOAM -- Pathways Intern	42	42	42	-	-
Subtotal, FTE Allocation	**1,352**	**1,352**	**1,352**	**-**	**-**
NSF AOAM FTE Usage					
NSF AOAM -- Regular	1,255	1,310	1,310	-	-
NSF AOAM -- Pathways Intern	30	42	42	-	-
Subtotal, FTE Usage	**1,285**	**1,352**	**1,352**	**-**	**-**
Detailees to NSF	3	3	3	-	-
Total, Workforce (Usage)	**1,288**	**1,355**	**1,355**	**-**	**-**

Totals may not add due to rounding.

NSF's FY 2017 FTE allocation of 1,352 represents no change from the FY 2016 Estimate. The FY 2017 estimated FTE usage is held equal to the FY 2016 Estimate of 1,310 regular and 42 Pathways FTE.

The regular FTE usage total includes the positions necessary to advise, coordinate, and centralize evaluation and data coordination activities associated with the NSF Evaluation and Assessment Capability, staff a Digital Service Team, and implement NSF's plans associated with the Digital Accountability and Transparency Act (DATA Act) and the Federal Information Technology Acquisition Reform Act (FITARA).

Personnel Compensation and Benefits (PC&B) (+$4.02 million, to a total of $225.37 million)

Personnel Compensation & Benefits

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Regular FTE Usage (projected)	1,255	1,310	1,310	-	-
Student FTE Usage (projected)	30	42	42	-	-
Regular FTE Base Salary	$154.96	$164.80	$166.53	$1.73	1.0%
Student Salary	1.22	1.60	1.64	0.04	2.5%
Other Compensation[1]	1.84	2.40	2.40	-	-
Awards	2.01	1.92	1.91	-0.01	-0.5%
Subtotal, FTE Compensation	**$160.03**	**$170.72**	**$172.48**	**$1.76**	**1.0%**
Benefits	44.68	46.10	47.88	1.78	3.9%
Other Benefits[2]	0.90	2.43	2.43	-	-
Subtotal, Benefits	**$45.58**	**$48.53**	**$50.31**	**$1.78**	**3.7%**
COLA[3]	-	2.09	2.58	0.49	23.4%
Total, PC&B	**$205.61**	**$221.35**	**$225.37**	**$4.02**	**1.8%**
Source of Funds:					
AOAM Appropriaton	199.63	215.53	219.55	4.02	1.9%
Administrative Cost Recoveries[4]	5.98	5.82	5.82	-	-
Total, Resources for PC&B	**$205.61**	**$221.35**	**$225.37**	**$4.02**	**1.8%**

Totals may not add due to rounding.

[1] Includes reimbursable details to NSF and terminal leave.

[2] Includes Federal Employee's Compensation Act (FECA) funding, overseas rental housing and education allowance, transit subsidies, and employee relocations.

[3] In FY 2016: includes nine months of the pay raise of 1.3 percent; which increases FTE Compensation costs by $1.63 million and Benefits by $457,000. In FY 2017: includes nine months of the projected pay raise of 1.6 percent; it increases FTE Compensation costs by $2.01 million and Benefits by $570,000.

[4] ACR levels for FY 2016 and FY 2017 are estimated based on the levels in FY 2014.

The total FY 2017 Request amount for Personnel Compensation and Benefits (PC&B) of $225.37 million represents an increase of $4.02 million over NSF's FY 2016 Estimate. Funding for PC&B reflects funding from two sources: $219.55 million in AOAM direct appropriated funds; and $5.82 from Administrative Cost Recoveries (ACRs) received during the year.

The PC&B cost estimate will support the projected FY 2017 year-end usage of 1,310 regular full-time equivalent (FTE) employees, a total of 42 Pathways intern FTE, a projected FY 2017 pay raise of 1.6 percent, associated cost of benefits, general workforce performance awards (GWFPA) set at one percent of the salary pool, and Senior Executive Service (SES) bonuses based on 7.5 percent of the SES salary pool. The FY 2017 estimate for PC&B also contains $930,000 for the Federal Transit Benefits Program. Amounts necessary to cover required agency costs associated with the OPM data breach will also be funded from within the PC&B total.

Management of Human Capital (+$200,000, to a total of $10.20 million)

Management of Human Capital
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$8.08	$10.00	$10.20	$0.20	2.0%

This level of funding would enable NSF to maintain basic operational support activities, training and development programs essential for NSF's permanent and rotator staff, and limited contractual support for human capital initiatives. These funds will be used to conduct NSF activities in support of the President's Management Agenda, ensuring NSF is able to make progress in all areas of the government-wide People and Culture objectives. The $10.20 million in the FY 2017 Request, an increase of $200,000 over the FY 2016 Estimate, will support:

- +$130,000, to a total of $1.06 million for NSF's basic HR systems accessed through shared service providers, such as the Federal Personnel Payroll System, the time and attendance system (WebTA), eRecruit capabilities using USAJobs, and an increased level of personnel security and suitability investigations for incoming staff.
- +$700,000, to a total of $3.20 million for the day-to-day operational support for recruiting, hiring, and on-boarding of permanent and rotating staff, as well as processing support for pay and benefits and incentive and other awards. The increase will provide additional support for these activities, including the adjudications of personnel security and suitability investigations, to help ensure a smooth transition of the workforce to NSF's new headquarters in anticipation of increased staff turnover associated with the move.
- +$105,000, to a total of $920,000 for workplace and work-life support for employees through NSF's health and family-friendly activities, including the Health Unit, Employee Assistance Program and child care subsidy. The additional funds will enable NSF to provide an increased level of support for employees as they transition to the new headquarters, including the need for health units in both the current and new headquarters due to the staggered nature of the move.
- +$75,000, to a total of $2.78 million for contracts in support of training and development programs, such as the Learning Management System, LearnNSF, and related on-line training capabilities, as well as support for training and networking activities including the NSF mentoring program, executive and supervisory training, and program management training. The increase will support training and development activities designed to help ensure that the workforce, including permanent and rotating staff, as well as new supervisors and executives, are equipped with the tools needed to transition to the new headquarters with minimal impact on mission accomplishment.
- A total of $200,000 (no change) for other program support (including outreach and licenses for key on-line reference materials, etc.).
- -$810,000, to a total of $2.05 million for strategic human capital support contracts. This decrease in funding is possible due to NSF's planned investment in business intelligence and other tools, supported in the FY 2016 Estimate, which are anticipated to reduce the cost of contract support. NSF relies on strategic human capital support contracts for assistance in developing new approaches to critical human resource needs including those identified and highlighted in NSF's Strategic Review process, Strategic Goal 3: Excel as a Scientific Federal Agency, Strategic Objective 1: Build an increasingly diverse, engaged high performing workforce by fostering excellence in recruitment, training, leadership, and human capital management.

The FY 2017 funding level for Management of Human Capital will allow NSF to complete the implementation of a set of high-priority explicit strategies, begun in FY 2015 and continued throughout

FY 2016, to retain at least 70 percent of NSF's current permanent staff through the transition to the new headquarters location in 2017, and to replace both the rotator population and retirements anticipated between now and then. Strategies include a mix of workforce planning, recruitment and hiring approaches, and retention strategies. These strategies will be refined through the continued use of regular exit and engagement interviews.

Travel (no change, to a total of $5.45 million)

NSF Employee FTE Travel

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate	
			Amount	Percent
$5.51	$5.45	$5.45	-	-

The FY 2017 Request amount of $5.45 million is held flat with the FY 2016 Estimate. This funding total is based on the travel activity associated with full utilization of 1,310 regular FTE coupled with the amount of site reviews, post-award monitoring and oversight, and outreach activities related to the projected level of program activities contained in the FY 2017 Request.

Information Technology (+$3.61 million, to a total of $25.60 million)

NSF funds administrative information technology (IT) applications from the AOAM account while mission-related IT investments that support the merit review process are funded from program accounts. Resources to support mission-related IT investments are discussed in the Program Related Technology (PRT) section of the Program Accounts: R&RA and EHR chapter.

Administrative applications services and support; associated IT operations and infrastructure; and related security and privacy services funded by the AOAM account are discussed below.

AOAM Information Technology

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate	
				Amount	Percent
Administrative Applications Services and Support	$6.86	$5.11	$6.73	$1.62	31.7%
Administrative IT Operations and Infrastructure	17.53	13.84	15.84	2.00	14.5%
Administrative Security and Privacy Services	2.79	3.03	3.03	-	-
Total, AOAM IT	**$27.18**	**$21.99**	**$25.60**	**$3.61**	**16.4%**

Totals may not add due to rounding.

Information technology for agency operations ensures high quality, reliable, and secure administrative applications and associated IT infrastructure support and services to meet the needs of the Foundation.

For FY 2017, NSF's information technology priorities for AOAM include:

- Implementing electronic invoicing. NSF is exploring options and may use a shared service provider to implement in FY 2017. This activity would support the Shared Services cross-agency priority (CAP)

goal*:* to strategically expand high-quality, high value shared services to improve performance and efficiency throughout government.[1]
- Enhancing the security of NSF's infrastructure to respond to the ever-evolving threat landscape in support of the Cybersecurity CAP goal: improve cybersecurity performance through ongoing awareness of information security, vulnerabilities, and threats impacting the operating information environment, ensuring that only authorized users have access to resources and information; and the implementation of technologies and processes that reduce the risk of malware.[2]
- Supporting the continued operation of iTRAK, the Foundation's financial management system, and the requirements of the Digital Accountability and Transparency (DATA) Act.
- Supporting preparation of IT systems for relocating to the new NSF headquarters and operating parallel infrastructures during the relocation.
- Making high priority changes to support the efficiency and effectiveness of NSF's administrative applications services, including NSF collaboration sites (SharePoint) and property and procurement applications.

<u>Administrative Applications Services and Support (+$1.62 million, to a total of $6.73 million)</u>
Investments in this category support administrative applications, such as the NSF website, NSF's human resources management systems, and iTRAK.
- iTRAK is NSF's financial management system. In FY 2017, the total request for iTRAK is $7.75 million. Seventy percent of this request will be funded by R&RA and EHR accounts and 30 percent will be funded by AOAM. The AOAM portion of the iTRAK request is increased, +$620,000, to a total of $2.33 million, to fund high priority change requests, the implementation of electronic invoicing, a potential new shared service planned for FY 2017, and to make changes to iTRAK to support the requirements of the Digital Accountability and Transparency (DATA) Act.
- Other administrative applications services funding increases, +$1.0 million, to a total of $3.05 million, to make high priority changes to administrative systems to ensure the continued effective operation of NSF's property and procurement applications and upgrade to the current version of SharePoint to ensure continued operation of collaboration sites and their continued interoperability with NSF's desktop services.
- A total of $1.35 million (no change) will be used for ongoing operations and maintenance of the systems that support the strategic management of NSF human capital, including those that enable the effective recruitment, retention, development, and use of NSF staff and that align with NSF's Strategic Goal 3: Excel as a Scientific Federal Agency, Strategic Objective 1: Build an increasingly diverse, engaged high performing workforce by fostering excellence in recruitment, training, leadership, and human capital management.

<u>Administrative IT Operations and Infrastructure (+$2.0 million, to a total of $15.84 million)</u>
Investments in this category provide basic maintenance and operations for ongoing activities that support administrative applications and services. This infrastructure includes NSF's data center, network, hosting, phone, email, and remote access services.

Additionally, this category includes the administrative support portion of NSF's help desk services. NSF provides customer care support for internal users 13 hours per day, five days per week.

The $2.0 million increase requested for FY 2017 will support the preparation of IT systems for relocating to the new NSF headquarters, to further increase the security of NSF's infrastructure in response to the ever-evolving threat landscape, and to run parallel infrastructures during the relocation, as services and staff are transitioned from the current NSF headquarters to the new location.

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[1] www.performance.gov/node/3398/view?view=public#overview
[2] www.performance.gov/node/3401/view?view=public#overview

Administrative Security and Privacy Services (no change, to a total of $3.03 million)
Investments in this category include automated configuration management tools that manage security patches and provide proactive protection from viruses, spyware, and other threats. This includes the portion of NSF's network security, application security, security control testing and tools, automated vulnerability assessment tools, and remediation and intrusion detection services related to administrative applications.

Space Rental (-$1.73 million, to a total of $32.44 million)

Space Rental
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate	
			Amount	Percent
$34.00	$34.17	$32.44	-$1.73	-5.1%

Space Rental includes services provided by the General Services Administration (GSA) related to rent and taxes, utilities, and security provided by the Department of Homeland Security.

The FY 2017 Request for Space Rental is $32.44 million, a decrease of $1.73 million, or -5.1 percent, below the FY 2016 Estimate. NSF currently occupies over 665,000 square feet of space, primarily in two adjoining, leased office buildings located in Arlington, Virginia. The current leases for both Stafford I and Stafford II have been replaced by interim occupancy agreements that extend occupancy until the upcoming move of NSF to Alexandria, Virginia. The interim occupancy agreements were negotiated by GSA with the current landlord and reflect current market rates for the Arlington area. The FY 2017 Request includes 12 months of rent at the current buildings in Arlington and one month of rent at the new facility in Alexandria.

The decrease of $1.73 million in FY 2017 reflects savings realized through application of the Tenant Improvement Allowance toward space rental in the final year of the current occupancy agreements. NSF will utilize this option in the leases to offset rent costs in the final three months of occupancy at Stafford I and II, resulting in a net savings to the agency. Additional savings in FY 2017 will be realized through the application of a broker's commission credit that will be applied to offset the rent costs of the new NSF facility in Alexandria.

Operating Expenses (+$1.54 million, to a total of $22.40 million)

Operating Expenses
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate	
			Amount	Percent
$15.78	$20.86	$22.40	$1.54	7.4%

The FY 2017 Request for Operating Expenses is $22.40 million, an increase of $1.54 million over the FY 2016 Estimate. Operating Expenses include funding for supplies and equipment, contracts, and other costs necessary to enable accomplishment of NSF's research and education mission, as well as to support a wide variety of financial and award management, leadership, and other activities.

The key activities funded by NSF's FY 2017 Request are described below.

- A total of $11.35 million (no change) for training, equipment, communications devices, printing, and supplies for NSF's directorates and offices. This level is based on the amount of funding required for the regular FTE usage of 1,310 projected for FY 2017.
- +$460,000, to a total of $4.49 million supports NSF's annual risk assessment, post-award monitoring and oversight (including advanced monitoring and large facility business systems reviews), contract close-out, and NSF outreach activities and materials. The increase over the FY 2016 Estimate reflects recent actual expenditure rates and costs resulting from contract re-competition.
- A total of $1.35 million (no change) provides financial management support, including financial statement reporting, NSF property reporting, audit deficiencies resolution assistance, and reporting associated with the financial system.
- +$250,000, to a total of $900,000 for NSF's internal control quality assurance activities: documenting, testing, and assessing internal control effectiveness, including effectiveness and efficiency of operations, reliability of financial reporting, and compliance with applicable laws and regulations. The increase over the FY 2016 Estimate is due to the anticipation of increased internal control audit requests.
- +$400,000, to a total of $680,000 provides support for the review of grantee expenditures for improper payments as per the Improper Payments Elimination and Reduction Act (IPERA), NSF's grant accrual, and Award Cash Management Service (ACM$) in order to project an error rate for expenditures and determine if there is a material effect on awardee financial reporting. The results of these analyses are used to support NSF's post-award monitoring programs. The increase over the FY 2016 Estimate reflects IPERA Stage 2 Statistical Testing.
- +$32,000, to a total of $516,000 to provide dedicated help desk support for the Office of Budget, Finance, and Award Management (BFA) to maintain and update BFA's technology resources and ensure efficient and expedient responses, minimizing interruptions to BFA's systems and services; contractor support for the Annual Large Facilities Workshop to include conference center space, lodging, guest speakers, and other related logistical and planning support; administrative support for document and correspondence preparation, accounts payable support, year-end close-out support, meeting management, site visit travel preparation, and SBIR financial capability assessments; and an interagency agreement that supplements NSF efforts in meeting a federal mandate to negotiate indirect cost rates for awardees over which NSF has cognizance. The increase over the FY 2016 Estimate is due to contract inflation costs, partially offset by capitalizing on the expected availability of unexpended funds, and will allow NSF to maintain a necessary level-of-effort to ensure continuity of services into FY 2018.
- +$21,000, to a total of $396,000 supports of NSF's Enterprise Information System (EIS) and the Budget Internet Information System (BIIS) to provide accurate, consistent information on financial data, funding rate, award size, and other statistics to NSF staff and the public. The increased support ensures that the system and related data analysis will continue to respond to evolving information needs and is integrated with iTRAK. The 5.5 percent increase over the FY 2016 Estimate reflects a standard increase in estimated costs and software licensing renewal fees.
- +$388,000, to a total of $388,000 provides dedicated, on-site, project management support to plan, coordinate, and execute NSF's implementation of the Digital Accountability and Transparency Act (DATA Act).
- -$38,000, to a total of $322,000 maintains on-going licensing, subscription, and infrastructure support for the Automated Acquisition Management System (AAMS) – NSF's E-procurement system. The decrease below the FY 2016 Estimate reflects the removal of Time & Materials costs.
- +$12,000, to a total of $300,000 supports administrative grants processing duties including, processing funding actions, reviewing payment requests, and answering inquiries. In addition, this includes verifying Davis-Bacon Act reports. The increase over the FY 2016 Estimate is due to contract inflation costs.

- A total of $250,000 (no change) is for reasonable accommodations that NSF is responsible for providing to persons with disabilities, including NSF employees, applicants, and those conducting business at NSF. Activities supported assist with maintaining NSF's model Equal Employment Opportunity status; not providing accommodations could be viewed as discrimination according to Sections 501 and 505 of the Rehabilitation Act of 1973.
- A total of $250,000 (no change) will provide support for increased cost analysis responsibilities due to the implementation of Standardized Cost Analysis Guidance, which became effective June 2014.
- A total of $250,000 (no change) provides contract support and purchase card program review and transaction support.
- A total of $220,000 (no change) provides funding for the congressionally-mandated Committee on Equal Opportunities in Science and Engineering (CEOSE) activity. This request covers contractor services and meeting support for the CEOSE. CEOSE is an NSF advisory committee that provides advice on policies and programs to broaden participation of women, minorities, and persons with disabilities.

Building and Administrative Services (+$1.02 million, to a total of $14.09 million)

Building and Administrative Services

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Information Dissemination	$1.85	$2.93	$2.49	-$0.44	-15.0%
Workplace Management	6.61	5.03	5.56	0.53	10.5%
Panel Support, Meeting Management, and Proposal Services	5.23	5.11	6.03	0.92	18.0%
Total, Building & Administrative Services	**$13.69**	**$13.07**	**$14.09**	**$1.02**	**7.8%**

Totals may not add due to rounding.

The FY 2017 Request of $14.09 million represents an increase of $1.02 million over the FY 2016 Estimate. The funding associated with Building and Administrative Services will support three sets of activities: information dissemination; workplace management; and panel support, meeting management, and proposal services.

Information Dissemination (-$440,000, to a total of $2.49 million)

Investments in this category fund activities that support NSF's website and intranet operations and maintenance, as well as graphic and user interface design. These funds support extensive web-based and electronic information distribution tools that provide information to both NSF staff and the public regarding the NSF mission and related content. This category also includes funding for website and business application development and user experience support, graphic design and commercial printing, and regulatory reporting processing and production.

The recent retirement of dated infrastructure and the conversion of content to modern platforms has allowed a decrease in costs associated with maintenance and support of the NSF website. The reduction of $440,000 below the FY 2016 Estimate is realized through the cost savings provided by these modernization efforts and supports two key pillars of the President's Management Agenda - Effectiveness: delivering world-class customer service to citizens and businesses; and Efficiency: enhancing productivity and achieving cost savings across the Government.[3]

[3] www.whitehouse.gov/sites/default/files/omb/memoranda/2015/m-15-11.pdf

Workplace Management (+$530,000, to a total of $5.56 million)
Workplace Management provides funding for core business activities and infrastructure support related to security and emergency management, such as security badge issuance, management of NSF Continuity of Operations Plan activities, physical security, and access control. Funding in this category also supports space management and facility operations, including development of space plans and assignments, space reconfigurations, and facility service and maintenance. Additionally, this funding supports activities related to property and records management – the oversight and planning of mailroom shipping and receiving operations; property receipt, inventory, and tracking; and the establishment and execution of records management policies and procedures.

The $530,000 increase over the FY 2016 Estimate is planned for contract escalation due to increased workload related to the NSF relocation and the continuation of uninterrupted support during the NSF transition to its new headquarters facility. This funding is required to temporarily support dual operations at both the existing and new facility for ID card office operations, facilities management, and reception and information center operations. Due to the planned staggered move schedule for relocation to the new facility, operations will be required to assist staff at both locations throughout the phases of the move.

Panel Support, Meeting Management, and Proposal Services (+$920,000, to a total of $6.03 million)
Investments in this category are used to provide critical support at all stages of NSF's merit review process (including pre, during, and post-review customer support). This funding also includes services provided in the scheduling and coordination of onsite and virtual panels; activities to oversee, operate, and maintain mission critical virtual communications equipment and resources; management of central conference space and audiovisual and communications equipment; travel management services for NSF staff and panelists; technical support and management oversight of proposal processing; and library and research assistance. Activities in this category support the Customer Service CAP goal: deliver world-class customer services to citizens by making it faster and easier for individuals and businesses to complete transactions and have a positive experience with government.[4]

In FY 2017, an increase of $920,000 over the FY 2016 Estimate will be applied to two activities:

- $160,000 will be used to support the increased workload related to travel management services for NSF staff and panelists. Onsite support resources are currently understaffed and unable to deal with the volume of requests related to travel assistance for both NSF staff and panelists. As these travelers support a critical function of the agency, this investment is necessary to ensure adequate assistance is available to guarantee the continued successful conduct of panels and merit review functions.
- NSF's print shop and proposal processing unit currently utilize printing and binding equipment and maintain central copiers throughout the Foundation that are reaching the end of their useful lifespan. Additionally, the new NSF Headquarters will have a space configuration different than the current print shop. An investment of $760,000 will be used to purchase equipment for the print shop and proposal processing unit at the new NSF facility and replace the obsolete printing and binding equipment and copiers.

[4] www.performance.gov/node/3400?view=public#apg

NSF Headquarters Relocation ($43.29 million)

NSF Headquarters Relocation
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate[1]	FY 2017 Request
NSF Headquarters Relocation	$2.70	$8.93	$28.79
Settlement Costs	-	-	14.50
Total, HQ Relocation	**$2.70**	**$8.93**	**$43.29**

Totals may not add due to rounding.
[1] There is still uncertainty regarding the FY 2016 funding requirements. Updated funding levels will not be available until after the FY 2017 Request is presented to Congress.

NSF headquarters has been located in Arlington, VA since 1993. Initially, the agency occupied the Stafford I building and subsequently expanded into an adjacent building (Stafford II) as the mission, operations, and staff grew over the 20-year lease period. Interim leases for both are in place through 2017.

Over the past several years NSF has worked collaboratively with the General Services Administration (GSA) to procure a new long-term lease to replace the Stafford I and II leases which expired during 2013. On June 7, 2013, GSA awarded a new 15-year lease for approximately 660,000 rentable square feet in Alexandria, VA.

NSF funding is required to manage the effort, furnish the building, incorporate IT infrastructure and other technology and security systems into the new building, and cover the costs of the physical move. The acquisition of these goods and services began in FY 2015 and will continue in FY 2016, FY 2017, and FY 2018 to complete the project design, construction, and occupancy on schedule.

The FY 2017 Budget Request includes funds for:
Program Management Costs ($2.59 million)
Funding in this category is for technical contractor expertise in the areas of:

- Project coordination, architecture and design management, and engineering and construction management;
- Interior design coordination and management;
- Furniture specification and procurement support;
- Relocation planning leading to final occupancy and turnover; and
- Information technology planning between existing NSF systems and the new headquarters.

Technology Costs ($10.37 million)
Funding in this area continues procurements for IT and mission technology, including:

- Design and engineering of specialized IT services and equipment, installation and integration;
- External building connectivity and internal backup equipment; and
- Critical IT building infrastructure systems such as secure data, video-teleconferencing components, routers, and virtual technology tools and systems.

Furniture, Fixtures and Equipment Costs ($7.71 million)
Funding will be used to complete activities associated with acquiring new furniture, including:

- Design, specification, coordination, delivery and installation of approximately 2,000 systems and/or modular furniture for NSF offices and workspaces; and
- Design, specification, coordination, and integration of high density and associated filing systems.

Move Costs ($3.38 million)
Funding in this category is required to award contracts to relocate NSF's staff, furniture, equipment, and other materials to its new location in a multi-phased move, with dual operations, where necessary, as the new headquarters is ready for occupancy.

Other Costs ($4.75 million)
Funding is required for an adequate project contingency and acquisition fees associated with personal property procurements.

Settlement Costs ($14.50 million)
Settlement costs must be paid to the lessor for the acceleration of substantial completion of the building by August 31, 2017. This amount includes landlord costs due to NSF delays, additional financing/opportunity costs, and 12 months of 2017 real estate taxes payable to the City of Alexandria (if an adjustment cannot be obtained from the City).

AOAM by Object Class

AOAM by Object Class

(Dollars in Thousands)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request[1]	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
Personnel Compensation	$154,071	$166,530	$168,260	$1,730	1.0%
Personnel Benefits	45,209	48,987	50,880	1,893	3.9%
Travel and Transportation of Persons	5,523	5,450	5,450	-	-
Transportation of Things	391	380	380	-	-
Rental Payments to GSA	34,000	34,168	46,940	12,772	37.4%
Rent to Others	-	-	-	-	N/A
Communications, Utilities and Misc. Charges	2,149	3,688	4,768	1,080	29.3%
Printing and Reproduction	178	113	146	33	29.3%
Advisory and Assistance Services	42,975	46,610	54,325	7,715	16.6%
Other Services	12,267	10,187	11,894	1,706	16.7%
Purchases of Goods & Srvcs from Gov't. Accts	6,207	8,640	10,635	1,995	23.1%
Operations and Maintenance of Equipment	583	400	1,552	1,152	288.0%
Supplies and Materials	1,389	3,257	3,712	455	14.0%
Equipment	1,618	1,590	14,079	12,489	785.5%
Land and Structures	-	-	-	-	N/A
Total, AOAM	**$306,560**	**$330,000**	**$373,020**	**$43,020**	**13.0%**

Totals may not add due to rounding.

[1] This table reflects recent updates and may not match what is shown in the President's Budget Appendix.

FY 2017 Request Object Class Code estimates mirror the FY 2017 request for AOAM and similarly reflect an increase of $43.02 million over the FY 2016 Estimate, including $43.29 million for costs associated with NSF’s relocation to Alexandria.

Personnel Compensation and Benefits: Personnel compensation funds payroll, awards/bonuses, reimbursable details to NSF, overtime, and terminal leave. Personnel Benefits include the Government’s contribution towards retirement systems, health and life insurance, thrift saving plans, special overseas allowances, unemployment insurance, transit subsidies, and employee relocations.

Personnel Compensation increases by $1.73 million over the FY 2016 Estimate to support the projected 1.6 percent pay raise in FY 2017.

Personnel Benefits increase by $1.89 million over the FY 2016 Estimate as a result of the 1.6 percent pay raise.

Travel and Transportation of Persons: These resources fund travel required for planning, outreach, and the increased oversight of existing awards recommended by the agency's Inspector General.

Transportation of Things: This category consists of household moves associated with bringing new staff to NSF.

Rental Payments to GSA: This category includes the rent charged by GSA for NSF's facility in Arlington, Virginia, and additional floors currently leased in an adjacent building. Rental Payments to GSA includes $32.44 million for space rental and $14.50 million for settlement cost associated with NSF's relocation to Alexandria.

Communications, Utilities, and Miscellaneous Charges: This category includes all costs for telephone and other communication lines and services, both local and long distance, and postage.

Printing and Reproduction: This category includes contract costs of composition and printing of NSF's publications, announcements, and forms, as well as printing of stationery and specialty items.

Advisory and Assistance Services: This category includes development, learning, and career enhancement opportunities offered through the NSF Academy; contracts for human capital operational activities, work life initiatives, outreach, and related services; assistance in award oversight and monitoring; support for OMB Circular A-123 reviews; and program management costs in support of NSF's new headquarters.

Other Services: This category includes warehousing and supply services, mail handling, proposal processing, equipment repair and maintenance, building-related costs, furniture repair, contract support for conference room services, security investigations, and miscellaneous administrative contracts.

Purchases of Goods and Services from Government Accounts: This category includes reimbursable services purchased from other government agencies. Examples include GSA for security guard services, some electrical upgrades, and modest renovation services, and Department of the Interior for payroll services.

Operation and Maintenance of Equipment: This category includes management and operation of the central computer facility 24x7 year-round; operation of the customer service center and FastLane help desk; maintenance of database server hardware and related peripherals; software licensing fees; data communications infrastructure and network systems support; electronic mail support; and remote access (e.g., internet and World Wide Web). In FY 2017, this category includes an increase to support the preparation of IT systems for relocation to the NSF headquarters.

Supplies and Materials: This category includes office supplies, library supplies, paper and supplies for the NSF central computer facility, and miscellaneous supplies.

Equipment: This category includes new and replacement computing equipment, desktop computers, data communications equipment, video-teleconferencing equipment, office furniture, file cabinets, and support equipment such as audio-visual equipment. In FY 2017, this category includes costs for the procurement of furniture and equipment for NSF's new headquarters in Alexandria.

Appropriations Language

For agency operations and award management necessary in carrying out the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.); services authorized by section 3109 of title 5, United States Code; hire of passenger motor vehicles; uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; rental of conference rooms in the District of Columbia; and reimbursement of the Department of Homeland Security for security guard services; ~~$330,000,000:~~*$373,020,000*: *Provided*, That not to exceed $8,280 is for official reception and representation expenses: *Provided further*, That contracts may be entered into under this heading in fiscal year ~~2016~~*2017* for maintenance and operation of facilities and for other services to be provided during the next fiscal year: *Provided further*, That of the amount provided for costs associated with the acquisition, occupancy, and related costs of new headquarters space, not more than ~~$30,770,000~~*$40,700,000* shall remain available until expended.

Agency Operations and Award Management
FY 2017 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Unobligated Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Obligations Actual/ Estimates
FY 2015 Appropriation	$325.00	-	-$18.11	-$0.33	$306.56
FY 2016 Estimate	330.00	18.11			348.11
FY 2017 Request	373.02				373.02
$ Change from FY 2016 Estimate					$24.91
% Change from FY 2016 Estimate					7.2%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Agency Operations and Award Management** (AOAM) no-year account, $18.11 million was carried over into FY 2016.

- NSF Headquarters Relocation
  - Amount: $18.11 million
  - Reason: Obligations planned for FY 2015 have been shifted to FY 2016.
  - Anticipated Obligation: FY 2016 Quarter 2

NATIONAL SCIENCE BOARD (NSB) $4,380,000
+$10,000 / 0.2%

The FY 2017 Budget Request for National Science Board (Board) is $4.38 million, an increase of $10,000 from the FY 2016 Appropriation of $4.37 million. The FY 2017 Budget Request will enable the Board to fulfill its policymaking responsibilities for NSF. It will also allow the Board to continue its responsibilities as outlined in the National Science Foundation (NSF) Act of 1950, including activities related to the review of major research facilities projects.

National Science Board Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, NSB	**$4.15**	**$4.37**	**$4.38**	**$0.01**	**0.2%**
Full-Time Equivalents (FTEs)	18	19	19	-	-

Totals may not add due to rounding.

Appropriations Language

For necessary expenses (including payment of salaries, authorized travel, hire of passenger motor vehicles, the rental of conference rooms in the District of Columbia, and the employment of experts and consultants under section 3109 of title 5, United States Code) involved in carrying out section 4 of the National Science Foundation Act of 1950 (42 U.S.C. 1863) and Public Law 86–209 (42 U.S.C. 1880 et seq.), ~~$4,370,000:~~*$4,380,000*: *Provided*, That not to exceed $2,500 shall be available for official reception and representation expenses. *(Science Appropriations Act, 2016.)*

National Science Board
FY 2017 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Expired	Obligations Actual/ Estimates
FY 2015 Appropriation	$4.37	-$0.22	$4.15
FY 2016 Estimate	4.37		4.37
FY 2017 Request	4.38		4.38
$ Change from FY 2016 Estimate			$0.01
% Change from FY 2016 Estimate			0.2%

Totals may not add due to rounding.

National Science Board in Context

The National Science Board, established by the NSF Act of 1950, has dual responsibilities to: a) provide national science policy advice to the President and Congress; and b) establish policies for NSF. The Board consists of 24 presidentially-appointed members plus the Director of NSF as an *ex officio* member. Representing the broad U.S. science and engineering (S&E), research and education community, the Board serves collectively as an advisory body on S&E issues critical to the U.S. Board members serve six-year terms on staggered appointments and are drawn from industry, academe, non-profit organizations and professional scientific societies representing the breadth of S&E disciplines. They are selected for their eminence in research, education, or public service.

The Board currently convenes four formally scheduled public meetings per year, with additional meetings as needed. In these meetings, the Board reviews and approves major NSF awards and new programs; oversees and provides policy direction to NSF; and addresses significant S&E related national policy issues. The Board initiates and conducts studies and reports on a range of policy topics. The Board reviews NSF's priorities to ensure progress and consistency along the strategic direction set for NSF and to ensure balance among new investments and core programs.

Policy Responsibilities

The Board examines issues of importance to the science, engineering, and education communities in general and to NSF in particular. Topics for exploration are determined through requests from Congress or the President, and as the Board identifies in consultation with the science community and NSF management. Recent reports have examined topics such as administrative burdens on researchers, merit review, mid-scale instrumentation, data policies, public research universities, science and engineering education, and the U.S. innovation system.

In addition to these special studies, the Board has several standing committees to assist with its responsibilities. The **Committee on Audit and Oversight** provides general supervision for the NSF Inspector General; oversight of major agency administrative processes and principal administrative systems; and review of the agency's internal controls.

The **Committee on Strategy and Budget** (CSB) focuses on strategic planning and new investments for NSF; analyzes NSF's budget to ensure progress and consistency in relation to NSF's strategic direction; and identifies strategic (typically long-term) issues critical to NSF's future. Within CSB, the **Subcommittee on Facilities** provides guidance and review of NSF-funded research equipment and facilities portfolio, including Major Research Equipment and Facilities Construction (MREFC) account funded facilities as well as Research and Related Activities account funded facilities.

The **Committee on Education and Human Resources** (CEH) focuses on policy and advice on major issues related to the NSF education, informal science, and training portfolio. It also provides advice on major national policy issues in science, technology, engineering, and mathematics (STEM) education, human resource needs and employment, and human resource development for the Board's consideration.

The **Committee on Science and Engineering Indicators** (SEI) oversees the development and production of the Board's biennial report, *Science and Engineering Indicators* (*Indicators*) and other related reports. The Board's publication of *Indicators* is a statutory responsibility. The 2016 edition of *Indicators*[1] was transmitted to Congress and the President on January 11, 2016.

The Board is responsible for direct review and approval of NSF's largest awards, such as awards greater than 1 percent of the awarding directorate's or office's prior year current plan, or awards 0.1 percent or more of NSF's total prior year enacted budget. It is responsible for the review and approval of MREFC projects at all stages of development, including budget planning, review of proposals and management effectiveness, and approval of awards. The **Committee on Programs and Plans** (CPP) provides guidance and advice on major policy issues related to the NSF Research and Related Activities (R&RA) portfolio, reviews proposals representing a significant expenditure of agency resources, and makes recommendations, as appropriate, to the full Board for its consideration and action. CPP also provides oversight, guidance,

[1] www.nsf.gov/statistics/2016/nsb20161/#/

and advice on major policy and operational issues related to the NSF polar research portfolio.

The Board's **Executive Committee** (EC) includes the Director of NSF, who chairs the EC, and four elected members from the Board. The Board may delegate its powers and functions granted by the NSF Act to the Executive Committee or to the Director of NSF or both.

Ongoing activities of the Board include review and approval of the following:

- Large awards, MREFC projects and other proposals as needed;
- NSF's Management Response to the Office of Inspector General (OIG) Semiannual Reports to Congress;
- The NSF, OIG, and the NSB budget submissions to the Office of Management and Budget (OMB);
- The priority order of projects in the MREFC Account;
- Inclusion of new project(s) requiring funding under the MREFC Account; and
- The NSF Strategic Plan.

The Board also reviews and makes recommendations on the following from NSF:

- Financial management reports for NSF;
- The operation of NSF's merit review system;
- NSF research infrastructure portfolio; and
- NSF human capital reports.

Office of the National Science Board
Personnel Compensation and Benefits and Other Operating Expenses
(Dollars in Thousands)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Personnel Compensation Benefits (PC&B)[1]	$2,901	$3,126	$3,136	$10	0.3%
Staff Development and Training	42	36	36	-	-
Advisory and Assistance Services	936	721	721	-	-
Travel and Transportation of Persons	199	344	344	-	-
Communications, Supplies, and Equipment	68	140	140	-	-
Representation Costs	-	3	3	-	-
Total, NSB	**$4,146**	**$4,370**	**$4,380**	**$10**	**0.2%**
Full-Time Equivalent	18	19	19	-	-

Totals may not add due to rounding.

[1] FY 2017 PC&B includes a pay raise of 1.6 percent, as well as anticipated within grade and promotion increases.

Personnel Compensation and Benefits

The Board's FY 2017 budget supports a core of full-time policy, communications, administrative, legal, and operations staff. In addition to providing institutional memory for the Board, the Board Office staff provides both the resources and expertise for coordinating and implementing science and education policy analyses and development, broad communication and outreach programs, advice to the Board on legal aspects of its policies and activities, and operational and administrative support that are essential for the Board to fulfill its mission.

Other Operating Expenses

The Board's Advisory and Assistance Services budget line includes the resources needed to produce policy reports such as *Indicators*. Over the past several years, the Board has heightened its efforts to increase the accessibility of *Indicators* and to facilitate the use of *Indicators* data in policy decisions and analysis.

Most of the Board's reports require expert analysis from organizations such as the Science and Technology Policy Institute—a Federally Funded Research and Development Center supported by NSF. Another major item in the Advisory and Assistance Services line is the development and maintenance of a high priority content management system (CMS). This CMS enables the efficient search, identification, and retrieval of relevant documents for reference and research purposes. Additionally, this CMS houses substantive Board materials, such as discussions, decisions, formal resolutions, and meeting minutes. This critical system assists our efforts in meeting the requirements of transparency, participation and collaboration as directed in the 2009 OMB Memorandum on Transparency and Open Government. The development of this system will continue to be a high priority. Other costs within the Advisory and Assistance Services line are associated with the Open Government initiative including the webcasting and archiving of all open Board meetings, as well as transcription services, report printing and dissemination.

NSB's Travel and Transportation of Persons budget line primarily covers Board member travel costs to NSF headquarters for the Board's four annual meetings and a member-only retreat, as well as travel for invited speakers and participants in Board activities. The Communications, Supplies, and Equipment budget line funds the range of electronic purchases, upgrades and installations, such as copiers and computers.

The FY 2017 Budget Request will facilitate the continued, thoughtful enhancement of the Board's media and online engagement efforts. These efforts have successfully informed the general public as well as the science, engineering, and education communities about the Board's activities, its published reports and other informative materials. The Board will continue to expand the community it serves on issues and activities relevant to S&E research and education through enhanced outreach capabilities that include developing best practices to reach and engage with targeted stakeholders.

OFFICE OF INSPECTOR GENERAL (OIG) $15,200,000

+$40,000 / 0.3%

The Appropriations Act that funds the National Science Foundation (NSF) provides for a separate appropriation for NSF's Office of Inspector General (OIG). Accordingly, this FY 2017 Budget Request identifies the resources needed to support OIG, including amounts for personnel compensation and benefits (PC&B), contract services, training, travel, supplies, materials, and equipment.

The FY 2017 Budget Request for OIG is $15.20 million, an increase of $40,000 from the FY 2016 Appropriation of $15.16 million.

Office of Inspector General Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Total, OIG	**$14.60**	**$15.16**	**$15.20**	**$0.04**	**0.3%**
Full-Time Equivalents (FTEs)	68	75	68	-7	-9.3%

Appropriations Language

For necessary expenses of the Office of Inspector General as authorized by the Inspector General Act of 1978, ~~$15,160,000,~~*$15,200,000* of which $400,000 shall remain available until September 30, ~~2017.~~*2018*. *(Science Appropriations Act, 2016.)*

Office of Inspector General

FY 2017 Summary Statement

(Dollars in Millions)

	Enacted/ Request	Unobligated Balance Available Start of Year	Unobligated Balance Available End of Year	Adjustments to Prior Year Accounts	Transferred	Obligations Actual/ Estimates
FY 2015 Appropriation	$14.43	$0.40	-$0.17	-$0.06	-	$14.60
FY 2016 Estimate	15.16	0.17			-	15.33
FY 2017 Request	15.20				-	15.20
$ Change from FY 2016 Estimate						-$0.13
% Change from FY 2016 Estimate						-0.8%

Totals may not add due to rounding.

Explanation of Carryover

Within the **Office of Inspector General (OIG)** two-year account, $171,000 was carried over into FY 2016.

- Office of the Inspector General
  - Amount: $171,000

- Reason: Funds are expected to be used to procure audit and forensic contracts. The selection of awards and institutions to be audited will require careful preparation and is subject to changing circumstances and new information that may require additional time to process.
- Anticipated Obligation: FY 2016 Quarter 2

OIG Responsibilities

In February 1989, the National Science Board established OIG pursuant to the Inspector General Act Amendments of 1988. The statute confers on OIG the responsibility and authority to:

- Conduct and supervise audits of NSF programs and operations, including organizations that receive NSF funding;
- Conduct investigations concerning NSF programs and operations, including organizations that receive NSF funding;
- Evaluate allegations of research misconduct, such as fabrication, falsification, or plagiarism, involving individuals who participate in NSF-funded activities;
- Provide leadership, coordination, and policy recommendations for:
    - Promoting economy, efficiency, and effectiveness in the administration of NSF programs and operations, and
    - Preventing and detecting fraud and abuse in NSF programs and operations; and
- Keep both agency management and Congress fully and currently informed about problems, recommended corrective actions, and progress being made in improving the management and conduct of NSF programs, to include the issuance of a Semiannual Report to Congress.

OIG performs audits of grants, contracts, and cooperative agreements funded by NSF's programs. The office also conducts audits and reviews of both internal agency programs and external organizations that receive NSF funding to ensure that financial, administrative, and programmatic activities are conducted economically, effectively, and in compliance with agency and federal requirements. OIG also oversees the audit of NSF's annual financial statements, which are required for all NSF accounts and activities by the Government Management Reform Act of 1994. OIG also audits financial, budgetary, and data processing systems used by NSF to prepare the financial statements. In addition, the office performs multi-disciplinary reviews – involving auditors, attorneys, management analysts, investigators, scientists, and others as needed – of financial, management, and program operations to identify broader problems and highlight best practices.

OIG investigates possible wrongdoing by organizations and individuals who seek or receive NSF funds such as those who submit proposals to, receive awards from, conduct business with, or perform work for NSF. Allegations of research misconduct by NSF recipients are also investigated. OIG assesses the validity and seriousness of all the allegations it receives to determine whether or not to pursue legal or administrative action. When appropriate, the office refers the results of these investigations to the Department of Justice or other authorities for criminal prosecution, civil litigation, or resolution via settlement agreements and institutional compliance plans. OIG refers some cases to NSF for administrative resolution and when indicated will recommend modifications to agency policies and procedures to ensure the integrity of NSF's business systems. The Office works closely with institutions on their internal research misconduct investigations and regularly engages in activities aimed at preventing and detecting fraud, waste, and abuse; and at raising the awareness of funded researchers, institutional administrators, and agency employees about OIG's role and NSF's rules and expectations.

Because diverse skills, training, and experience are necessary to oversee NSF's many programs, the OIG staff includes scientists, attorneys, certified public accountants, criminal investigators, management analysts, evaluators, and information technology specialists. The subjects of investigations, audits, and other reviews are also varied and may include: an individual grant recipient or institution; a broad program or functional area of NSF; or a project involving multiple disciplines or entities. In addition, OIG utilizes contractors to perform work when it is cost effective, or when it lacks the necessary expertise in-house, as in the case of the annual review of the agency's financial systems controls and its compliance with the Federal Information Security Management Act (FISMA).

Office of Inspector General
Personnel Compensation and Benefits and General Operating Expenses
(Dollars in Thousands)

	FY2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
Personnel Compensation and Benefits[1]	$11,222	$11,916	$12,010	$94	0.8%
Travel & Transportation of Persons	263	270	295	25	9.3%
Advisory & Assistance Services[2]	2,881	2,498	2,413	-85	-3.4%
Rent	55	77	82	5	6.5%
Information Technology	12	197	195	-2	-1.0%
Communications, Supplies, Equipment & Other Services	170	202	205	3	1.5%
Training	*97*	*150*	*120*	*-30*	*-20.0%*
Other	*73*	*52*	*85*	*33*	*63.5%*
Total, OIG	**$14,603**	**$15,160**	**$15,200**	**$40**	**0.3%**
Full-Time Equivalents	68	75	68	-7	-9.3%

Totals may not add due to rounding.

[1] Includes projected 2017 pay raise of 1.6 percent, as well as anticipated within grade and promotion increases.

[2] Includes the costs of the annual financial statements audit and the outsourcing of contracting services.

An FY 2017 appropriation of $15.20 million will enable OIG to carry out the core elements of its mission and maintain a workforce of about 68 FTEs, the same number employed in FY 2015. However, sharply rising personnel and contract costs will limit investments in training, technology, a forensic IT program, and other key areas.

Recent budget cuts have impacted the number of audits and investigations performed, as our workforce declined 17 percent from 78 staff at the start of FY 2013 to just 65 during July 2014. During FY 2015, we were able to add 4 professional staff to program areas where workload imbalances are of greatest concern. As our current workforce ages, new hires are critical to revitalizing our workforce and will be carefully vetted not just for technical skills but also for their readiness to assume future management responsibilities. In FY 2017, we estimate that 29 percent of our staff (mostly managers) will be eligible to retire.

Between FY 2013 and FY 2015, OIG has sustained an increase in its average cost per FTE of about 13 percent, as raises and awards have resumed, the cost of benefits has increased, and professionals such as lawyers, investigators and CPAs replace departing administrative staff who were less expensive. While management understands that returning OIG staffing levels to what they were before FY 2013 may not be realistic, we believe that being able to maintain a workforce of at least 68-70 FTEs is necessary to effectively perform our mission.

OIG has streamlined its administrative unit, electing to allocate as many FTEs as possible for audits and investigations. OIG's priorities in the near term are to increase the number of audits and investigations conducted from the low level of production that occurred during sequestration in FY 2013. To achieve this, OIG will: assure that the necessary number of audit contracts can be procured and that there are an adequate number of internal audit staff to monitor them; and continue rebuilding the civil/criminal investigative unit, which has lost a number of investigators to mandatory retirement. Investments in equipment and technology upgrades (e.g., expansion of our data analytics capability for Audits and Investigations) will continue to be pursued as funds allow. Funding for preventive activities, such as educating researchers at regional conferences about rules and requirements associated with federal grants, as well as other outreach efforts to stakeholders, will continue at a slightly reduced level. Other costs includes a resumption of the obligation to pay for Council of Inspectors General for Integrity and Efficiency of $44,000.

Office of Audits (OA). The Office of Audit (OA) expects to see a significant increase in its costs in FY 2017 as it faces challenges to sustaining its current workload. Audit work required by statute has grown in recent years from auditing NSF's financial statements and compliance with the Federal Information Security Management Act (FISMA), to reviewing compliance with new legislation, such as the Improper Payments Elimination and Recovery Act (IPERA), and the Digital Accountability and Transparency Act (DATA Act). These new audit responsibilities will require additional staff hours and funding for contractors. In FY 2015, the cost of the Financial Statements and FISMA contract was about $900,000. That contract is being re-competed in FY 2016, and the cost is expected to increase by as much as 33 percent due to the new IPERA and DATA Act audit work.

The increased costs for the OIG's mandatory work will reduce the portion of OA's FY 2017 budget available for discretionary audits, which target high-risk programs and institutions. The universe of potential discretionary audits is large, consisting of about 2,000 institutions and 11,000 new awards each year. Historically, the OA audit plan includes about 40 discretionary audits. To perform these audits, OA utilizes the services of the Defense Contract Audit Agency (DCAA), Independent Public Accounting (IPA) firms, and in-house audit staff. The 2016 National Defense Authorization Act, which prohibits DCAA from accepting work from non-defense agencies, is also likely to increase audit costs as the work given to DCAA is replaced with private sector contracts.

Much of our discretionary audit work recently has focused on NSF's management of its large facilities. NSF will spend hundreds of millions of dollars in coming years on projects such as the National Ecological Observatory Network (NEON), Large Synoptic Survey Telescope (LSST), Ocean Observatories Initiative, and the Daniel K. Inouye Solar Telescope. Strong oversight is crucial to ensuring that these projects are financially sound and properly managed.

To cite just one example, NEON is in the midst of constructing a $433.80 million facility. Beginning in 2011, auditors identified serious flaws in NEON's proposed construction budget and issued three inadequacy memos along with an adverse opinion on the proposed budget. Within the proposal, OIG found $154 million in questioned and unsupported costs (approximately 36 percent of the total budget). Our warnings about NEON's finances were validated in June 2015 when NEON management informed NSF that the project was facing a potential cost overrun of $80 million.

And NEON is not the only high-risk construction project underway. In 2014, we issued an alert to NSF regarding proposed costs for its $467.70 million LSST project. We found that NSF did not have sufficient information to establish a reasonable basis for the cost of this project and could not justify costs for major categories such as salaries and equipment, the same concerns earlier expressed about NEON. Construction on the LSST project is underway; about $44 million has been spent, and we have already identified cost and schedule risks. We are preparing an alert on NSF's oversight of the project to provide feedback to the agency while there is still time to prevent cost overruns, schedule delays, and other problems, both on LSST and its other large facility projects.

In addition, during FY 2017 NSF will be in the final crucial stages of completing its move to a new headquarters in Alexandria, VA. OIG has played an important role in overseeing this transition and has made valuable recommendations to improve efficiency and effectiveness. The need for such oversight will increase dramatically as the move date draws closer, thus requiring a sustained commitment of in-house audit resources and the possible use of a contracted expert to assist with technical issues.

OA will continue its strategy to maximize the effectiveness and efficiency of its audit practices by selecting auditees and audit programs with a two-phase analytics methodology. In Phase I, OA will use data analytics to identify the risk of misuse of NSF funds on all open awards. During this exercise, the Office will mine NSF and other databases for known fraud indicators such as suspicious awardee drawdowns, and institutions that have been suspended or debarred, in order to develop a list of auditees. In Phase II, OA will use data analytics to analyze institutions' general ledger and sub-ledger data to identify anomalous transactions for testing and/or further research to determine if award funds are being misspent. Since OA began using data analytics for audit planning in FY 2012, it has been able to significantly increase audit coverage by reviewing 100 percent of transactions with automated processes. Each year the Office also refines its risk assessment model by continually adjusting factors and weights to enhance its ability to identify problematic or questionable costs.

OA has altered its operations model in recent years to increase efficiency in two ways. It has: 1) reduced the scope of work for IPAs by performing some of the data analytics for them, and 2) procured fewer IPA audits by developing in-house grant-audit capabilities. These two strategies each have the potential to reduce audit costs. The first strategy draws on the experience of OA's staff in auditing NSF grants to identify the riskiest transactions in the data. OA then provides the data sets with identified risk areas to the IPA firms to perform the transaction testing on site at the audited institutions. Using this combination of in-house staff and contracted audit support leverages OA's knowledge of NSF and data analytics, making it less critical to employ experienced grant auditors to perform the fieldwork.

The second strategy involves developing grant and cooperative agreement audit capability among OA staff. To accomplish this, the Office pairs its data analytics team with experienced in-house audit staff to develop and execute audit programs. The data analytics team identifies the highest risk areas at an institution, and the OA auditors perform audit fieldwork to test these areas. The Office is also including newer OA staff as trainees in this process to help them develop their grant-audit knowledge and capabilities. Both strategies aim to save money by reducing the use of contracted audits, while increasing staffing flexibility and helping to address quality issues that OA has experienced with some contractors.

Office of Investigations (OI). Over the years, investments in OIG's Office of Investigations have consistently yielded an excellent return for the government. Over the last ten years, our investigative activities have resulted in well over $40,000,000 in recoveries and return of funds put to better use. In FY 2015 we recovered $7.60 million in government funds, up 183 percent from FY 2014. In addition to recoveries of funds and civil and criminal convictions, our cases frequently produce both financial settlements for institutional fraud that include compliance agreements aimed at strengthening internal controls and systems to better protect federal funding in the future.

Since the beginning of FY 2013, however, OI has sustained a net loss of three FTEs or ten percent of its investigative staff due to attrition. These individuals were among our most experienced, knowledgeable, and skilled investigators. Unable to afford filling these positions, we instead increased the number of active cases carried by each criminal and research misconduct investigator by 20 percent in order to handle our inventory of open investigations. This resulted in delays in completing investigations, presenting cases to U.S. Attorneys for prosecution, and issuing reports of investigation to NSF to resolve instances of personnel misconduct and systemic weaknesses identified in the reports. This was particularly detrimental in the area of civil/criminal investigations. While we have concluded a significant number of cases and returned our caseload per criminal investigator to previous levels, the overall number of open cases has by necessity decreased, as we adjust to a more sustainable investigative caseload.

Staff shortages have also delayed development and implementation of the OI electronic case management system, eLOC. Unable to retain a long-sought forensic IT specialist for OI, we substituted a staff investigator to serve as subject matter expert and procurement development advisor for this initiative, which has further exacerbated workload imbalances. Finally, operating with reduced investigative staff has required that we be more selective in the issues we pursue to full investigation in an effort to conserve and prioritize our scarce resources. While our performance measured in terms of recoveries and funds put-to-better-use remains high, our ability to maintain that momentum over time depends upon establishing and maintaining staffing levels that are able to carry a larger caseload.

Budget cuts have also impaired our efforts to aggressively address the increase in financial frauds within the SBIR/STTR programs, an area of continuing special Congressional concern. New Small Business Innovative Research (SBIR) Program investigations have declined from 33 in calendar year 2012 to 24 in 2014, and 22 in 2015 due to the lack of available investigative staff. The establishment of the SBIR Investigative Working Group opened an effective dialogue within the OIG community about the pursuit of SBIR fraud, and resulted in a higher profile for such cases and numerous joint investigations. Our office has helped lead this multi-agency effort since its inception, and sustaining a high level of commitment to combating SBIR fraud has been a top priority.

OIG Support Functions. Office-wide support functions (apart from information technology) fall under the executive leadership of an Assistant Inspector General (who also serves as OIG's Legal Counsel) and are encompassed within two operating units. The Immediate Office consolidates a number of functions that have historically worked together, but which were formerly aligned under the direct supervision of the Inspector General -- legal, legislative/congressional, and external affairs (including public/media contacts). The staff also actively supports government-wide projects in which NSF OIG has taken a leadership role, including those focused on increasing the use and effectiveness of suspension and debarment remedies to protect taxpayer funds; preventing and detecting fraud, waste, and abuse in the SBIR Program; and providing broad support to the Inspector General in her role as Vice Chair of Council of Inspectors General for Integrity and Efficiency (CIGIE).

The Office of Management is responsible for performing strategic planning/budgeting, procurement, human resources, and administrative support and is currently comprised of just three staff. Organizational alignment of the two units under a single executive subordinate to the IG has saved money and afforded some synergistic benefits to the organization. To assure that there are adequate resources available for our core mission of audits and investigations, support functions within the Office of Management and elsewhere across the OIG have been streamlined to the maximum extent practical.

An Assistant Counsel was hired in FY 2015 to strengthen office-wide legal support. Besides providing comprehensive legal advice, counsel, and critical analysis to the IG and all OIG divisions, the legal activity also administers financial disclosure requirements for OIG staff; performs certain functions related to the Freedom of Information and Privacy Act; represents the office in external forums; and also enables the office to engage in proactive efforts (such as training and routine reviews) to recognize and deal with legal concerns as early as possible.

Information Technology. Spending on hardware, software, and IT services in FY 2017 is expected to remain relatively level. OIG plans to reduce its costs for computers and printers in FY 2017 by lengthening their replacement cycle, phasing out the use of desktop printers and relying more on network printers. Costs to license existing software, which totaled about $84,400 in FY 2015, are fixed in the short term but their use is reevaluated each year. License fees are required to receive the periodic software updates and assistance that are necessary to sustain audit and investigations operations.

IT service costs in FY 2015 of about $44,000 included network printer maintenance, cellular service for mobile devices, and internet service for the OIG Denver office. In FY 2017, OIG hopes to realize some modest savings by reducing the cost of its cellular service through more efficient management of its cellular devices and services.

Preventive initiatives. Budget considerations have forced OIG to reduce many of its initiatives aimed at fulfilling its core mission to prevent fraud, waste, and abuse. These include our efforts to address the issues underlying: 1) a general erosion of research integrity, as evidenced by a threefold increase in allegations in the past decade, and studies indicating that 25 to 30 percent of scientists engage in questionable research practices; 2) the increasing number of allegations of serious misconduct committed by scientists from other countries who may not understand U.S. rules and procedures; and 3) SBIR program fraud.

In the past, our staff has played a key role in educating the agency's stakeholders on matters related to grant fraud and research misconduct. OIG's proactive efforts help to assure the integrity of federally-funded research by promoting effective oversight of NSF-funded activities *at the institutional level*. We ensure the research community understands the civil, criminal, and administrative ramifications of running afoul of requirements incurred in conjunction with receipt of federal funds. In addition, OI's proactive program analysts have been very productive in generating leads that result in substantive new cases, and identifying systemic problems that affect NSF's grant administration process. Another important element of our proactive program is the use of database analysis tools. Their use has enabled OI to identify prospective NSF awardees that are high-risk recipients of federal funds based on their past misconduct or questionable practices.

However, budget constraints have required us to divert resources from our proactive program to ensure that audits and investigations are adequately funded, and prevented us from making full use of available technology to improve timely identification of high-risk grant applicants and systemic weaknesses. Our ability to continue a robust preventive program of proactive investigative reviews and effective outreach depends on staffing and travel resources, especially in light of our other urgent audit and investigative priorities, as set forth above. Robust interaction between OIG and the research community not only helps to promote research integrity and financial accountability, but also provides our investigators and auditors with valuable insights into the needs and concerns of the institutions and researchers.

Finally, along with the progress OIG has made in the use of data analytics to strengthen both its audit and investigative operations comes requests to share information about these new technologies and practices with the research community and other Federal agencies. Our outreach efforts aim to educate institutions about the advanced analytics we employ to: 1) provide insight on system and support requirements necessary to complete audit engagements in an efficient manner; and 2) teach institutions to improve business intelligence and assure accountability for Federal funds. In addition, many Federal audit offices have expressed interest in learning about and introducing analytics in their own programs to uncover additional risks. OIG has complied with these requests to the degree possible given our budgetary constraints. We anticipate a continuing – and increasing – need for such support.

MAJOR MULTI-USER RESEARCH FACILITIES

Major Multi-User Research Facilities Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate	
				Amount	Percent
Total Research and Related Activities	**$963.10**	**$979.67**	**$1,036.16**	**$56.49**	**5.8%**
Operations and Maintenance of Existing Facilities	736.77	697.25	732.08	34.83	5.0%
Federally Funded Research and Development Centers	215.51	212.88	215.58	2.70	1.3%
Operations and Maintenance of Facilities under Construction	7.12	55.04	81.00	25.96	47.2%
R&RA Planning and Concept Development	3.70	14.50	7.50	-7.00	-48.3%
Major Research Equipment and Facilities Construction	**$146.89**	**$203.31**	**$195.12**	**-$8.19**	**-4.0%**
Total, Major Multi-User Research Facilities	**$1,109.99**	**$1,182.98**	**$1,231.28**	**$48.30**	**4.1%**

Totals may not add due to rounding.

The FY 2017 Budget Request for major multi-user facilities is $1,231.28 million, of which $1,214.88 million is discretionary funding and $16.40 million is new mandatory funding. The new mandatory funding is within the Federally Funding Research and Development Centers ($1.30 million) and Operations and Maintenance of Existing Facilities ($15.10 million) lines in the above table.

NSF investments provide state-of-the-art tools for research and education. These include multi-user research facilities and instrumentation networks such as observatories, accelerators, detectors, telescopes, research vessels, aircraft, and simulators. In addition, investments in cyber-enabled and geographically distributed user facilities are increasing as a result of rapid advances in computer, information, and communication technologies. NSF's investments are coordinated with those of other organizations, federal agencies, and international partners to ensure they are complementary and well integrated. Planning, operations, and maintenance of multi-user facilities are funded through the Research and Related Activities (R&RA) account, and most major construction projects are funded through the Major Research Equipment and Facilities Construction (MREFC) account.

This chapter provides descriptions of each major multi-user research facility supported through the R&RA account and provides funding information by life cycle phase for each facility. The information presented for each facility follows the overall framework established by NSF for large facility projects. Information on projects under construction funded through NSF's MREFC account is provided in the MREFC chapter.

Major Multi-User Research Facilities Funding, by Project
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request[1]	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
Operations and Maintenance of Existing Facilities	**$736.77**	**$697.25**	**$732.08**	**$34.83**	**5.0%**
Engineering					
National Nanotechnology Coordinated Infrastructure (NNCI)	15.02	15.46	15.46	-	-
Natural Hazards Engineering Research Infrastructure (NHERI)	18.24	12.50	12.50	-	-
Geosciences					
Academic Research Fleet[2]	79.87	83.80	82.80	-1.00	-1.2%
Geodesy Advancing Geosciences and EarthScope (GAGE)	11.58	11.58	13.08	1.50	13.0%
International Ocean Discovery Program (IODP)	48.00	48.00	48.00	-	-
Ocean Observatories Initiative (OOI)	55.00	55.00	50.00	-5.00	-9.1%
Polar Facilities and Logistics	314.54	286.57	307.07	20.50	7.2%
Seismological Facilities for the Advancement of Geoscience & EarthScope (SAGE)	24.35	24.35	26.95	2.60	10.7%
Mathematical and Physical Sciences					
Arecibo Observatory	8.01	8.20	8.30	0.10	1.2%
Cornell High Energy Synchrotron Source (CHESS)[3]	21.97	18.03	20.00	1.97	10.9%
Gemini Observatory	20.61	19.88	20.42	0.54	2.7%
IceCube Neutrino Observatory	6.90	6.90	7.00	0.10	1.4%
Large Hadron Collider (LHC)	18.00	18.00	18.00	-	-
Laser Interferometer Gravitational Wave Observatory (LIGO)	33.00	39.43	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)[4]	35.92	22.78	35.78	13.00	57.1%
National Superconducting Cyclotron Laboratory (NSCL)	23.00	24.00	24.50	0.50	2.1%
Other Facilities[5]	2.77	2.77	2.79	0.02	0.7%
Federally Funded Research and Development Centers[6]	**$215.51**	**$212.88**	**$215.58**	**$2.70**	1.3%
National Center for Atmospheric Research (NCAR)	98.70	99.70	101.00	1.30	1.3%
National Optical Astronomy Observatory (NOAO)	25.50	21.60	21.83	0.23	1.1%
National Radio Astronomy Observatory (NRAO)[7]	83.31	82.08	75.25	-6.83	-8.3%
Other Astronomical Facilities[7]	-	-	11.50	11.50	N/A
National Solar Observatory (NSO)[8]	8.00	9.50	6.00	-3.50	-36.8%
Operations and Maintenance of Facilities under Construction	**$7.12**	**$55.04**	**$81.00**	**$25.96**	**47.2%**
Daniel K. Inouye Solar Telescope (DKIST)[9]	7.00	11.00	16.00	5.00	45.5%
National Ecological Observatory Network (NEON)	0.12	44.04	65.00	20.96	47.6%
R&RA Planning and Concept Development	**$3.70**	**$14.50**	**$7.50**	**-$7.00**	-48.3%
Pre-construction Planning[10]	3.70	14.50	7.50	-7.00	-48.3%
Major Research Equipment and Facilities Construction[11]	**$146.89**	**$203.31**	**$195.12**	**-$8.19**	-4.0%
Total, Major Multi-User Research Facilities	**$1,109.99**	**$1,182.98**	**$1,231.28**	**$48.30**	**4.1%**

Totals may not add due to rounding.

[1] The FY 2017 Request for major multi-user facilities is $1,231.28 million, of which $1,214.88 million is discretionary funding and $16.40 million is new mandatory funding. The new mandatory funding is within the NCAR ($1.30 million), GAGE ($1.50 million), SAGE ($2.60 million), and Polar Facilities and Logistics ($11.0 million) lines in the above table.

[2] Academic Research Fleet funding includes ship operations and upgrades. Regional Class Research Vessels (RCRV) funding is no longer included on this line as it is proposed for an FY 2017 MREFC new construction start.

[3] Forward funding for the Cornell High Energy Synchrotron Source (CHESS) of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[4] Forward funding for the National High Magnetic Field Laboratory (NHMFL) of $11.88 million in FY 2015 reduced the amount required in FY 2016.

[5] Other Facilities includes ongoing MPS support for the Center for High Resolution Neutron Scattering (CHRNS).

[6] Federally-Funded R&D Centers do not include support for the Office of Science and Technology Policy Institute (STPI), which is an FFRDC but not a multi-user research facility.

[7] Funding for the National Radio Astronomy Observatory (NRAO) includes operations and maintenance support for the Atacama Large Millimeter Array (ALMA). The decrease in FY 2017 is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now included under "Other Astronomical Facilities" in this table.

[8] National Solar Observatory (NSO) totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $14.0 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured within the total presented on the MREFC line.

[9] Of total DKIST funding presented, $5.0 million in FY 2015, $9.0 million in FY 2016, and $14.0 million in FY 2017 is for operations and maintenance support provided through the National Solar Observatory, and for all years, $2.0 million is for cultural mitigation activities as agreed to during the environmental compliance process. For more information, see the DKIST narrative in the MREFC chapter.

[10] Pre-construction planning includes funding for potential next generation multi-user facilities. This line reflects funding for Antarctic Infrastructure Modernization for Science (AIMS) for all three years and the Large Hadron Collider (LHC) upgrade for FY 2017 only. The LHC upgrade will be funded at $2.50 million in FY 2017.

[11] Funding for MREFC Projects in this table include support for concept and development associated with ongoing and requested MREFC projects, i.e. RCRV, provided through the R&RA account. RCRV funding is $2.13 million in FY 2015, $3.0 million in FY 2016, and $2.0 million in FY 2017.

NSF Facilities Investments in FY 2017

The following pages contain information on NSF's ongoing facilities in FY 2017.

ACADEMIC RESEARCH FLEET

$84,800,000
-$2,000,000 / -2.3%

Academic Research Fleet
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$82.00	$86.80	$84.80	-$2.00	-2.3%

The U.S. Academic Research Fleet includes 16 vessels in calendar year 2015, and 18 vessels in calendar year 2016. These vessels range in size, endurance, and capabilities, enabling NSF and other federally-funded scientists to conduct ocean science research with a diverse fleet capable of operating in coastal and open ocean waters. Funding for the Fleet includes investments in ship operations; shipboard scientific support equipment; oceanographic instrumentation and technical services; and submersible support. Funding levels reported here reflect investments in the Directorate for Geosciences (GEO) by the Division of Ocean Sciences (OCE). In addition to operations, OCE has undertaken selected construction projects based on inter-agency planning and coordination as discussed in the *Federal Oceanographic Fleet Status Report*[1] published in May 2013.

Total Obligations for the Academic Research Fleet
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$79.87	$83.80	$82.80	$80.80	$80.80	$80.80	$80.80	$80.80
RV Sikuliaq O&M[2]	*3.50*	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*
Fleet Modernization								
Regional Class Research Vessel	2.13	3.00	2.00	-	-	-	-	-
Total, Academic Research Fleet	**-**	**-**	**$84.80**	**$80.80**	**$80.80**	**$80.80**	**$80.80**	**$80.80**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only.

[2] As discussed in the R/V *Sikuliaq* paragraph below, operations and maintenance for the RV *Sikuliaq* are now included in Fleet Operations and Maintenance. Because the Academic Fleet is operated as a shared multi-agency resource where agencies pay for time uses on vessels, the annual OCE operating budget for any single vessel may vary significantly from year to year. Thus, estimates for the RV *Sikuliaq* for FY 2016 and beyond are provided as a rough guide of likely costs.

The U.S. Academic Research Fleet serves as the main platform for the collection of data and testing of hypotheses about the structure and dynamics of the ocean. Scientists contribute to advances in many areas including climate variability, marine ecosystems, fisheries, and ocean-related natural hazards, such as tsunamis, through use of these facilities. Participating graduate and undergraduate students interact with scientists and marine technicians, enabling them to gain first-hand exposure to ocean science field research. Increasingly, technological innovations allow research conducted at sea to be transmitted via satellite back to the classroom, broadening the educational impact of the vessels.

The Fleet is supported through an interagency partnership, principally with the Office of Naval Research (ONR) and the National Oceanic and Atmospheric Administration (NOAA). Operating costs for the Fleet are divided proportionally among the vessel users based on usage; NSF supports approximately 60 percent

[1] www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

of the total, which includes the Ocean Observatories Initiative's use of the Fleet. NSF coordinates with ship-operating and ship-user academic institutions both directly and through the University National Oceanographic Laboratory System (UNOLS) organizational structure.

Support for scientists using the Fleet is provided by both NSF and other federal and state agencies. Within NSF, science is funded through competitive peer-reviewed proposals, most typically funded within OCE and through selected programs in the Division of Earth Sciences (EAR), the Division of Atmospheric and Geospace Sciences (AGS), the Division of Polar Programs (PLR), and the Directorate for Biological Sciences (BIO). Approximately 25 percent of OCE proposals request ship time. Not reflected in this number is the science that utilizes samples or data collected on prior cruises, scientists piggy-backing on scheduled cruises to accomplish additional science, international scientists sailing with the U.S. Academic Research Fleet, and science funded by other agencies.

The FY 2017 Request of $82.80 million will support approximately 1,500 ship operating days.

<u>Fleet Operations/Management and Oversight</u>

- Oversight: NSF provides oversight to the Academic Research Fleet through cooperative agreements with each ship-operating institution and through a separate cooperative agreement with the UNOLS Office. NSF is the cognizant agency for ship operations rate negotiations. In addition, NSF oversees the Fleet through site visits, ship inspections, and participation at UNOLS Council and Committee meetings by NSF program directors. Several program directors within OCE at NSF, at NOAA, and at ONR are involved in the activities and oversight of the Academic Research Fleet.
- Management: Management of an institution's ship-operating facilities varies with the scale of the operation, but the core responsibility typically resides with the director of the institution, the marine superintendent (for all aspects of the facility), and the ship's captain (for at-sea operations). For larger multi-ship-operating institutions, a chief of marine technicians, schedulers, and finance administrators may also be involved in facility management.
- Reviews: Based on projected science requirements identified in recent reports and workshops, a fleet of vessels supporting ocean science research will be needed far into the future. Documents supporting this need include the *National Ocean Policy*[2] and the *Final Recommendations of the Interagency Ocean Policy Task Force*[3] of July 19, 2010. Two applicable reports by the National Research Council (NRC) include *Science at Sea: Meeting Future Oceanographic Goals with a Robust Academic Research Fleet*[4] published in 2009, and *Critical Infrastructure for Ocean Research and Societal Needs in 2030*[5] published in 2011. In coordination with UNOLS and the other federal agencies that invest in ocean research, the Interagency Working Group on Facilities and Infrastructure (IWG-FI) published a *Federal Oceanographic Fleet Status Report*[6] in May 2013, reviewing the status and describing plans for modernizing the federal and academic oceanographic research and survey fleet. In January 2015, The National Academy of Sciences Report *Sea Change 2015-2025 Decadal Survey of Ocean Sciences*[7] identified the U.S. Academic Research Fleet as having "the strongest match between current infrastructure and the decadal science priorities" and emphasized the overall importance of ships in all of the science priorities. Ship operations and technical services proposals undergo external review by peers every five years. Detailed annual reports describing activities accomplished are provided by the operating institutions and budgets are negotiated yearly since they are dependent on the number of days the ships will be at sea in support of NSF-funded research programs. No Business System Reviews of Academic Research Fleet operating institutions are currently scheduled for 2016.

[2] www.whitehouse.gov/sites/default/files/national_ocean_policy_implementation_plan.pdf
[3] www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf
[4] www.nap.edu/catalog/12775/science-at-sea-meeting-future-oceanographic-goals-with-a-robust
[5] www.nap.edu/catalog/13081/critical-infrastructure-for-ocean-research-and-societal-needs-in-2030
[6] www.whitehouse.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf
[7] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

Fleet Modernization

Oversight: The NSF coordinator for Fleet modernization activities is the program director for Ship and Submersible Support, within the Integrative Programs Section (IPS) in OCE, with additional IPS staff providing project management assistance as required.

Regional Class Research Vessel (RCRV): In March 2012, NSF leadership approved the request to advance the RCRV to the Conceptual Design Review (CDR) phase as a candidate Major Research Equipment and Facilities Construction (MREFC) project. On February 1, 2013, NSF made an award to Oregon State University (OSU) as the lead institution for advancement to CDR. Funds for CDR were provided from the Research and Related Activities account. In December 2013, OSU successfully completed all CDR requirements in accordance with NSF's Large Facilities Manual.[8] Approval for advancement to the Preliminary Design Phase was provided in March 2014. The Preliminary Design Review (PDR) was held in August 2014. The PDR Panel recommended the project be approved to advance to the Final Design Phase. Initial funds to initiate construction are requested in FY 2017, contingent on continued satisfactory progress by the awardee, the project's consistency with overall NSF goals and strategic direction, and the availability of funds. Personnel from the NOAA Office of Marine and Aviation Operations, as well as ONR, continue to participate in the review of the RCRV design and project management. In addition, NSF is an active participant in the IWG-FI Ship Subcommittee, which developed the update to the 2013 *Federal Oceanographic Fleet Status Report*, an action in the *National Ocean Policy (NOP) Implementation Strategy.*[9] The RCRV would address requirements across the government agencies for research vessels in support of ocean science research as discussed in the Fleet Status Report Update. Decisions on proceeding to further development stages will be based upon NSF, National Science Board (NSB), and interagency reviews.

R/V *Sikuliaq*, formerly the Alaska Region Research Vessel (ARRV): The Research Vessel *Sikuliaq* represents NSF's first major contribution to Fleet renewal in over twenty years. Construction of the *Sikuliaq* was funded through the MREFC account, partially with American Recovery and Reinvestment Act (ARRA) funds. The project is led by the University of Alaska, Fairbanks (UAF) with engineering support from design through construction provided by UAF's naval architect, The Glosten Associates, Inc. Shipyard construction began in early 2011 and the vessel was successfully launched in October 2012. Delivery of the *Sikuliaq* to UAF took place in June 2014. This was followed by a period of final outfitting, science trials, and transit to the first science operational area. Initial science operations began in late 2014. *Sikuliaq* has successfully completed ice trials in the Bering Sea and three science cruises in the Arctic Ocean. All final MREFC project activities will be closed out by the end of March 2016.

Research in the Arctic is needed on topics ranging from climate change, ocean circulation, ecosystem studies, and fisheries research, to natural hazards and cultural anthropology. The *Sikuliaq* provides a sophisticated and significantly larger platform for scientists, as well as graduate and undergraduate students to participate in complex multidisciplinary research activities and enables the training of the next generation of scientists with the latest equipment and technology. The *Sikuliaq* greatly expands research capabilities in the Arctic providing up to 270-300 science days at sea annually. The ice-strengthened hull allows the vessel to operate in seasonal ice up to one meter thick and an anti-roll tank permits it to operate effectively in the open waters of the Bering Sea, Gulf of Alaska, and North Atlantic.

Other Ongoing Activities

Major overhaul and upgrade to the submersible Human Occupied Vehicle *ALVIN* was completed in FY 2013. The *ALVIN* Upgrade project was scoped in two phases. Phase I was the integration of a new titanium 6,500-meter-capable personnel sphere with existing *ALVIN* vehicle components. Phase I

[8] www.nsf.gov/pubs/2015/nsf15089/nsf15089.pdf
[9] www.whitehouse.gov/administration/eop/oceans/implementationplan

completion provided a maximum depth capability of 4,500 meters, the limit of the legacy *ALVIN* components retained during Phase I. Phase II would provide upgrades to permit operations to a depth of 6,500 meters, but there has been no implicit or explicit commitment to proceed with Phase II at this time. Sea trials for operation of the Phase I vehicle in November 2013 supported certification for operations to 3,800 meters, and approximately 100 dives in support of science were made in 2014. Further sea trials to support certification to 4,500 meters were successfully completed in January 2015.

Renewal/Re-competition/Termination

Ships supported by NSF are operated by academic institutions, each having a cooperative agreement with NSF. All ship cooperative agreements were renewed in FY 2012 using the NSB-approved criteria and review by an external panel. Awardees are subject to additional oversight measures, including quarterly safety and financial reporting, the use of NSF Business System Reviews (BSR), and site inspections. In 2013, NSF retired *R/V Cape Hatteras*, operated by a consortium of Duke University and the University of North Carolina from its homeport at the Duke University Marine Laboratory. In 2014, NSF retired *R/V Point Sur*, operated by Moss Landing Marine Laboratories, San Jose State University. For the *R/V Sikuliaq*, a re-compete clause in ten years (2024) was included in the initial cooperative agreement for operations.

ARECIBO OBSERVATORY **$8,300,000**

+$100,000 / 1.2%

Arecibo Observatory

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$8.01	$8.20	$8.30	$0.10	1.2%

The Arecibo Observatory (Arecibo), formerly the National Astronomy and Ionosphere Center, is a center for multidisciplinary research and education enabled by world-class observational facilities. The observatory's principal facility is the world's largest single-dish radio/radar telescope, a 305-meter diameter reflector located near the town of Arecibo in western Puerto Rico on 120 acres of U.S. Government-owned land. Arecibo is currently operated and managed by SRI International and subawardees Universities Space Research Association (USRA) and Universidad Metropolitana (UMET) under a cooperative agreement with NSF that began on October 1, 2011. The observatory serves over 350 users annually with a wide range of research and observing instrumentation in passive radio astronomy, solar system radar astronomy, and space and atmospheric sciences. A peer-review telescope allocation committee provides merit-based telescope time to users. The committee is common to the three fields, but specific subject matter experts from outside the observatory are consulted for reviews. NSF does not provide awards targeted specifically for use of Arecibo, although some Arecibo users are supported through NSF or NASA grants to pursue scientific programs that require use of the facility.

Arecibo has a staff of about 122 full-time-equivalent positions at the beginning of FY 2016. A total of 97 permanent staff work for Arecibo. This includes approximately 20 scientists who, along with engineers, technicians, and operators, are available to help visiting investigators with observing programs. In addition, there are management, administrative, and clerical positions, as well as maintenance staff, and several postdoctoral scholars and students. There are 25 individuals involved at the Angel Ramos Foundation Visitor Center, including 18 temporary tour guides.

Total Obligations for the Arecibo Observatory

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance (MPS)	$4.01	$4.10	$4.20	$4.20	$4.20	$4.20	$4.20	$4.20
Operations & Maintenance (GEO)	4.00	4.10	4.10	4.10	4.10	4.10	4.10	4.10
Total, Arecibo	**$8.01**	**$8.20**	**$8.30**	**$8.30**	**$8.30**	**$8.30**	**$8.30**	**$8.30**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2016. NSF is exploring an extension through FY 2017.

Arecibo is jointly supported by the NSF Directorate for Mathematical and Physical Sciences, Division of Astronomical Sciences (MPS/AST) and the NSF Directorate for Geosciences, Division of Atmospheric and Geospace Sciences (GEO/AGS). Planned AST support through FY 2017 is based on the 2006 AST Senior Review recommendations, an external review of the MPS/AST portfolio conducted in 2012, and guidance from a third-party cost review of AST facilities. Based on Senior Review recommendations, MPS/AST has ramped down support for Arecibo, whereas GEO/AGS ramped up support through FY 2015.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*, the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, AST conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges,*[10] was released in August 2012 and included recommendations about all of the major AST telescope facilities. The MPS/AST PRC recommended that support for Arecibo should be continued at funding levels near those currently planned, with a re-evaluation later in the decade, based on science opportunities and budget forecasts at that time.

GEO/AGS is currently conducting a portfolio review of GEO/AGS Geospace research and infrastructure investments, including facilities such as Arecibo. The GEO/AGS portfolio review is expected to be completed in early FY 2016. This review completion and the re-evaluation timescale recommended by the MPS/AST Portfolio Review are roughly coincident with the expiration of the cooperative agreement at the end of FY 2016. In view of the long lead-time required for conducting a management competition, NSF has contracted a feasibility study for divestment alternatives, which will provide a baseline structural and environmental survey of conditions at Arecibo. This study, to be completed in Q2 FY 2016, is likely to be followed by a formal review to evaluate environmental impacts of viable divestment options, including the possible impacts of potential partnerships. In addition, in October 2015, NSF issued Dear Colleague Letter NSF 16-005[11] requesting the community to propose viable concepts for the long-term operation of Arecibo Observatory. NSF is presently evaluating the responses submitted for the January 15, 2016 deadline.

<u>Partnerships and Other Funding Sources</u>: Arecibo leverages NSF support with funding from other federal and non-federal sources. Since FY 2010, the NASA Near Earth Object Observation Program has committed $2.0 million annually to Arecibo in support of the planetary radar program; this was increased to $3.60 million for FY 2013, with more observing time allocated to the NASA Program. NASA support is expected to continue at approximately $3.70 million in FY 2016 and FY 2017, subject to the availability of funds. A grant to the Visitor Center from the Puerto Rico Department of Education was finalized in 2013. This award was for $1.90 million over seven months; part of this was to train teachers, as described in the next section, while part of it was to enable larger numbers of Puerto Rican school children to visit the site. Follow-on activities to this 2013 grant were conducted in 2014/2015.

An image of the Arecibo Radio Telescope in Puerto Rico. The platform suspension structure, including the Gregorian dome that houses the main suite of research instruments, is visible over the 305-meter primary reflector dish below. *Credit: Arecibo Observatory/NSF*.

<u>Education and Public Outreach (EPO)</u>: Arecibo hosts a Research Experiences for Undergraduates (REU) site, and Ph.D. students receive training through the use of the facility. In collaboration with the National Radio Astronomy Observatory (NRAO), Arecibo holds a summer school on single-dish radio astronomy

[10] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[11] www.nsf.gov/pubs/2016/nsf16005/nsf16005.jsp

techniques. Arecibo also sponsors a major outreach program in Puerto Rico via the Angel Ramos Foundation Visitor Center as well as summer workshops for K-12 teachers. This center attracts more than 80,000 visitors each year; over 1.4 million people have visited since its opening in 1997. Approximately 25 percent of these visitors are K-12 students. Exhibits at the visitor center are being updated in Q1 FY 2016, and physical renovations to the visitor center building are scheduled to begin in Q2 FY 2016. These improvements are funded by the Angel Ramos Foundation and the Ana G. Méndez University System, and have been formally approved by the NSF. With the funds mentioned above from the Puerto Rico Department of Education, Arecibo has hosted numerous teacher workshops, the most recent June 1-5, 2015, and has trained approximately 500 teachers. This program integrates formal activities at the Angel Ramos Foundation Visitor Center into the STEM curriculum in Puerto Rico. Arecibo also hosts several meetings each year within a wide variety of scientific disciplines.

Operations and Maintenance: Arecibo administers observing time to the astronomy and aeronomy communities via competitive observing proposals and conducts educational and public outreach programs at all levels. Observing hours among science programs are based on the quality of the observing proposals. The telescope is currently oversubscribed, counting ongoing astronomy surveys, new astronomy projects, solar system observations, and atmospheric sciences programs. About 80 percent of astronomy users conduct their observing remotely via networked control software, while radar observations typically employ on-site users.

Management and Oversight

- MPS/AST, $4.20 million: AST funds basic operations costs and science programs in passive radio astronomy and solar system radar astronomy. As recommended by the 2006 AST Senior Review, funding for Arecibo has been gradually reduced, declining to a lower baseline of $4.0 million in FY 2015. The modest increase in FY 2016, which continues into FY 2017, is a planned inflationary adjustment that was part of the baseline published in the solicitation for the Arecibo management competition carried out in FY 2010 and FY 2011. Arecibo operational scope has changed in response to decreased AST support
- GEO/AGS, $4.10 million: The incoherent scatter radar at Arecibo is part of an NSF-supported network of radars strategically distributed to observe the transport of radiative energy and charged particles, from their origins at the sun to their deposition in Earth's upper atmosphere. The unique sensitivity of the Arecibo incoherent scatter radar system allows it to measure the density, temperature, and motion of plasma in Earth's ionosphere with unrivaled time and spatial resolution. Arecibo is also the only aeronomy observatory located at tropical mid-latitudes, where many important ionospheric processes take place. Commissioning of an ionospheric high-frequency heating facility is underway at Arecibo in Q1 FY 2016.
- NSF Structure: Ongoing oversight is provided by the lead NSF program officer in AST, in close cooperation with an assigned program officer in AGS and in consultation with community representatives. The program officers make use of detailed annual program plans, long range plans, quarterly technical and financial reports, and annual reports submitted to NSF by SRI. They also attend SRI governance committee meetings, as appropriate. To address issues as they arise, the program officers work closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support; the Office of General Counsel; and the Large Facilities Office of the Office of Budget, Finance, and Award Management. The AST and AGS program officers conduct periodic site visits and frequent teleconferences.
- External Structure: Management is via a cooperative agreement with SRI and its sub-awardees, USRA and UMET. The awardees provide management and oversight through their own advisory and visiting committees, including an Arecibo Observatory Users Committee, a Scientific Management Advisory Committee, a Council of Puerto Rican Chancellors and Stakeholders, and an Executive Governing Committee. The principal investigator of the operations award resides at SRI headquarters in Menlo

Park, CA, but makes frequent site visits to Puerto Rico. The principal on-site management staff include the Arecibo site director, resident at the telescope site, a deputy director in the areas of Radio Astronomy and Planetary Radar, and a deputy director for Education and Public Outreach. The position of Arecibo site director is currently open, and is the subject of a broadly-based search being conducted by the managing organization.

- Reviews:
  - A review of the proposal for management and operations of Arecibo was held in 2010, resulting in an award to SRI (see below) from October 2011 to September 2016.
  - A Business Systems Review involving two of the partner organizations of Arecibo, SRI and UMET, was conducted in late 2012.
  - AST and AGS jointly conduct annual external reviews of Arecibo program plans; the most recent review was held in October 2013. The next program review will be held in early CY 2016. (A program plan review was not held in 2014, but was instead superseded by the mid-term management review held in late CY 2014; see next bullet below).
  - AST and AGS jointly conducted a mid-term management review of the Arecibo cooperative agreement in November 2014. The panel report was received early in calendar year 2015. Various recommendations of the panel are currently being incorporated into Arecibo Observatory operations.

Renewal/Competition/Termination

The current cooperative agreement with SRI for the management of Arecibo was awarded on October 1, 2011, when SRI succeeded the previous managing organization, Cornell University. This followed a competitive process for a new five-year cooperative agreement, consistent with National Science Board policy. This agreement is in effect through September 30, 2016. NSF is exploring an extension through September 30, 2017. The direction beyond that time will be determined after carrying out the study of divestment alternatives, receiving the recommendations of the GEO/AGS Geospace portfolio review, and evaluating the response to NSF 16-005, all of which were discussed above. There is potential for substantial change to the notional budgets shown above for FY 2018 and beyond, following completion of the evaluation process during FY 2016.

CORNELL HIGH ENERGY SYNCHROTRON SOURCE $20,000,000
+$1,970,000 / 10.9%

Cornell High Energy Synchrotron Source
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate[1]	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$21.97	$18.03	$20.00	$1.97	10.9%

[1] Forward funding of $1.97 million in FY 2015 reduced the amount needed in FY 2016.

The Cornell High Energy Synchrotron Source (CHESS) is a high-intensity, high-energy X-ray user facility supported by NSF with interagency support from the National Institutes of Health (NIH). It uses synchrotron light given off by charged particles, both electrons and positrons, as they circulate in a ring at nearly the speed of light. CHESS provides capabilities for X-ray research in physics, chemistry, biology, materials, engineering, and environmental sciences. Emphasis areas include soft matter and thin film studies, solution scattering, nanomaterials, high-pressure science, structural biology, time-resolved studies of materials, and X-ray studies of structural materials. Stewardship and oversight of CHESS is provided through the NSF Division of Materials Research within the Directorate for Mathematical and Physical Sciences (MPS/DMR), as well as the Directorates for Biological Sciences (BIO) and Engineering (ENG).

The FY 2017 Request supports operations of CHESS as a national user facility and is consistent with the planned annual funding level at $20.0 million. (Forward funding of $1.97 million in FY 2015 reduced the amount needed in FY 2016.) Support for CHESS has shifted over the past years from research and development to a national user facility, thus the facility's activities are evolving. Funding will allow continued operation of the facility in support of high energy X-ray synchrotron users.

Total Obligations for CHESS
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate[1]	FY 2017 Request	ESTIMATES[2] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance (MPS)	$11.97	$8.03	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Operations & Maintenance (BIO)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Operations & Maintenance (ENG)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total, CHESS	**$21.97**	**$18.03**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**

Totals may not add due to rounding.

[1] Forward funding of $1.97 million in FY 2015 reduced the amount needed in FY 2016.

[2] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2019.

CHESS is a national user facility accessed through competitive proposal review. The primary function of CHESS staff is to maintain and operate the facility and to assist users. Users number about 850 annually and perform a broad array of research including: computationally-enabled scattering studies of complex materials; an analysis of the structure of designer solids including the impact of processing; enabling the engineering of materials through time-resolved synchrotron radiation studies, x-ray imaging, and spectroscopic studies; studying structural materials under operating conditions; and the analyses of macromolecules and biochemistry. The latter topic is done in collaboration with NIH. An annual users' meeting and several workshops help disseminate results from the facility.

CHESS supports users from academia, industry, and national laboratories. CHESS is developing a dynamic testing station for structural materials through collaboration with the U.S. Air Force Research Laboratory and the Office of Naval Research. CHESS collaborates with Department of Energy (DOE)-supported synchrotron facilities such as the Advanced Photon Source and the National Synchrotron Light Source. X-ray detectors developed at CHESS are now in use at 3rd and 4th Generation X-ray sources around the world, including the world's first hard X-ray laser, DOE's Linear Coherent Light Source. CHESS-developed undulators, that cost an order of magnitude less than current technology, are being installed at CHESS. The undulators will increase X-ray flux by an order of magnitude and enable CHESS to pursue time-resolved and high resolution imaging experiments not previously possible. The Cornell undulators and other innovations such as high flux X-ray optics are impacting synchrotron science worldwide.

CHESS researchers also developed a new Kolsky bar apparatus to study the impact on structure of high strain rates using in situ diffraction from metals undergoing shock-wave induced strain. This unique capability uses the high flux of CHESS in combination with a new high speed pixel array detector. Understanding high impact deformation is particularly important to the automotive and aerospace industries.

CHESS supports and enhances Ph.D. level graduate education, postdoctoral research, and research experiences for undergraduates and for K-12 students and science teachers. Their education and outreach program annually impacts over 6,000 people of all ages, including over 1,300 visitors touring the Cornell facilities. Each year there are about 60 Ph.D. degrees granted as a result of CHESS research. CHESS is a key training ground for X-ray and accelerator scientists, with CHESS graduates being hired to staff other X-ray facilities in the U.S. and around the world.

Management and Oversight

- NSF Structure: CHESS is supported by MPS, ENG, and BIO through a cooperative agreement with Cornell University. A MPS/DMR program director is the primary contact with the facility and leads an internal NSF team of program directors. NIH provides additional support for CHESS operations through the Macromolecular Diffraction at the Cornell High Energy Synchrotron Source (MacCHESS) award. A Joint Operating Group (JOG) was established to better coordinate the CHESS and MacCHESS awards. The JOG serves as a vehicle to keep interested parties informed and includes program directors in MPS, ENG, and BIO at NSF, as well as NIH program directors.
- External structure: The Cornell Laboratory of Accelerator-based Sciences and Education (CLASSE), which reports to Cornell's Vice-Provost for Research, administers CHESS. The principal investigator serves as the CHESS Director and reports to the Director of CLASSE. The CHESS Director receives guidance primarily from the CHESS executive committee, from an external policy and advisory board, the CHESS diversity committee, and the users' executive committee.
- Reviews: NSF provides oversight by monitoring annual plans and reports including user metrics, as well as by conducting monthly phone conferences with the director. NSF uses annual site visit reviews to assess the user program, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. In addition to a panel of experts from the community, representatives from NIH attend these site visits. Recent and upcoming reviews include:
  - A Management Review focusing on CHESS operations and strategic planning, July 9-10, 2014.
  - Annual site review by external panel of site visitors, October 26-27, 2015
  - Annual site review, fall of 2016.

Renewal/Recompetition/Termination

A comprehensive renewal review was conducted in FY 2013. The National Science Board authorized an award to Cornell for the operation of CHESS of up to five years in duration and up to $100 million. The end date of the award is March 2019.

GEMINI OBSERVATORY

$20,420,000
+$540,000 / 2.7%

Gemini Observatory
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$20.61	$19.88	$20.42	$0.54	2.7%

The Gemini Observatory consists of twin optical/infrared 8-meter telescopes, one each in the northern and southern hemispheres. Gemini North sits atop Mauna Kea, Hawaii at 4,200 meters elevation, while Gemini South is located on the 2,700-meter summit of Cerro Pachón, Chile. This siting of the two telescopes provides complete coverage of the sky and complements observations from space-based observatories. Both telescopes offer superb image quality and employ sophisticated adaptive optics technology to compensate for the blurring effects of the Earth's atmosphere.

Among the fundamental questions being investigated by today’s astronomers are the age and rate of expansion of the universe, the origin of the “dark energy” that drives cosmic acceleration, the nature of non-luminous matter, the processes that give rise to the formation and evolving structures of galaxies, and the formation of stars and their planetary systems. The current generation of large optical/infrared telescopes is central to these studies, owing to their unsurpassed sensitivity and exquisite spatial resolution. Technological advances incorporated into the design of the Gemini telescopes optimize their imaging capabilities and infrared performance as well as their ability to rapidly reconfigure the attached instrumentation in response to changing atmospheric conditions.

The Gemini telescopes help educate and train astronomy and engineering students through internship programs for undergraduates in both Hawaii and Chile. Gemini also provides an engaging focal point for public outreach and student training in all of the partner countries, and maintains "sister city" arrangements between the host sites of Hilo, Hawaii and La Serena, Chile. Gemini-sponsored activities attract students and teachers at all levels of elementary through high school education. Gemini staff members also provide guidance and support to the Imiloa Science Center, a public astronomy and cultural center in Hilo, Hawaii.

The laser at Gemini-South produces synthetic guide stars on the sky, which the GeMS adaptive optics system uses to correct wide-field images for atmospheric turbulence. *Credit: Gemini/AURA.*

The international partnership that operates Gemini currently consists of the U.S., Canada, Brazil, Argentina, and Chile, with the U.S. as the majority partner. Construction of the telescopes and their instrumentation involved a large number of industrial entities in these and other countries, with areas of specialization that included large and/or complex optical systems, engineering, electronics, electro-mechanical systems, and computing. Continued development in these technological areas is reflected in the instrumentation and facilities renewal activities that are incorporated into the overall budget of the Gemini Observatory.

Total Obligations for the Gemini Observatory
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$20.61	$19.88	$20.42	$21.03	$21.66	$22.31	$22.98	$23.67

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2016.

Laser guide star systems, which greatly improve the ability to correct for atmospheric blurring, are available at both facilities. The advanced "multi-conjugate" adaptive optics system on Gemini South continues to lead the world, providing near-infrared images that exceed the quality available from orbiting observatories, and which cover a field-of-view on the sky that is wider than any competing system. Commissioned in 2014, the state-of-the-art Gemini Planet Imager is in regular use for directly imaging and characterizing planets orbiting nearby stars. Additional improvements to the multi-object spectrograph in Chile have greatly increased its utility in the far red spectral region.

The U.S. share of Gemini Observatory observing time is open to proposals by any researcher in the U.S. astronomical community, with peer-review allocation committees providing merit-based telescope time. NSF does not provide awards targeted specifically for use of Gemini. However, U.S. users are often supported through separate NSF research awards to pursue scientific programs that require the use of the observatory.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*,[12] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences in the Directorate for Mathematical and Physical Sciences (MPS/AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*[13] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

The PRC report ranked Gemini Observatory as a critical component of our Nation's future astronomical research resources and recommended that the U.S. retain a majority share in the international partnership for at least the next several years. However, given the constraints that were considered, the Committee recommended that the maximum U.S. contribution to Gemini operations in 2017 and beyond should be $17.0 million per year. Given the withdrawal of the United Kingdom and Australia from the Gemini partnership (see below) and the NRC recommendation that the U.S. increase its partner share in Gemini, the FY 2017 Budget Request for Gemini is higher than that recommended by the PRC.

The FY 2017 Request includes the full U.S. contribution to baseline operations at the level agreed to by the international partners ($18.56 million in FY 2017), and a contribution of $1.86 million to the Gemini Instrument Development Fund. Funding levels through FY 2021 have been agreed to by the post-2015 Gemini partners through a Gemini Board resolution in May 2015, and are reflected in the out-year estimates.

[12] www.nap.edu/catalog.php?record_id=12951
[13] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Management and Oversight

- NSF Structure: NSF has one seat on the Gemini Board, currently occupied by the MPS/AST division director. An additional NSF staff member serves as the executive secretary to the board. Programmatic oversight is the responsibility of an NSF program officer. The program officer monitors operations and development activities at the observatory, nominates U.S. scientists to Gemini advisory committees, conducts reviews on behalf of the partnership, and approves funding actions, reports, and contracts.
- External Structure: The observatory is governed by the Gemini Board, which was established by the International Gemini Agreement signed by the participating agencies. NSF serves as the executive agency for the partnership, carrying out the project on their behalf. The U.S. holds six of the 13 seats on the Gemini Board, and NSF appoints the five non-NSF members. The Board includes the director of the U.S. National Optical Astronomy Observatory (NOAO) in order to facilitate increased cooperation between NOAO and Gemini and to provide an improved voice for the general U.S. astronomical community. Gemini is currently managed by the Association of Universities for Research in Astronomy, Inc. (AURA) on behalf of the partnership through a cooperative agreement with NSF. AURA conducts its own management reviews through standing oversight committees.
- Reviews: NSF conducts periodic reviews of the management and operation of the observatory as requested by the Gemini Board. The most recent mid-term management review was held in September 2008. NSF conducted a Business System Review (BSR) of the observatory in March 2009, and several other AURA facilities, including its centralized administrative services, were the subject of a BSR in 2013. The current cooperative agreement with AURA for the operation of Gemini was awarded in March 2011 and again in August 2014. These extended the agreement through December 31, 2015 and through December 31, 2016, respectively. This one-year extension of the existing cooperative agreement to the end of 2016 resulted from a need to shift the re-competition away from other major NSF observatory management competitions being held in 2014 and 2015.

Renewal/Re-competition/Termination

The United Kingdom withdrew from the Gemini partnership at the end of 2012 in the midst of a major restructuring of that country's scientific priorities. This required the observatory to adjust its operations model to an approximately 24 percent reduction in budget, which will ultimately result in a reduction in total staffing from about 200 in FY 2011 to fewer than 160 by the end of FY 2018. Recently, Australia, a 6.3 percent partner in 2015, moved to a more limited participation on a year-to-year basis. Korea has a similar arrangement and has elected to continue its 2015 limited term collaboration with the observatory to the end of 2016. Discussions with Korea regarding full partnership have progressed rapidly during the last 18 months and arrangements are now being made for that nation to assume most of Australia's share in FY 2017. The international partners are currently negotiating a new agreement for the post-2015 years, and NSF expects this new agreement to be finalized in early 2016.

The current NSF cooperative agreement for managing the Gemini Observatory includes the transition to the new operations model. Reductions in project scope that accompany the decline in budget include a reduced instrument complement on each telescope, cost savings from a shift in nightly telescope operations from the remote telescope site to the base facility at sea level in Hawaii and Chile, a re-design of the data archive, decreased development and outreach activities, and a tighter focus on serving the partner user communities at the expense of internal scientific research activities. In February 2012 the National Science Board (NSB) approved the funding recommendation for this plan through 2015 and approved a one-year extension approved in May 2015. Re-competition of the management and operation of Gemini was conducted in 2014-2015. Proposals were solicited in August 2014 and received in February 2015. Face-to-face meetings between NSF and the proposing organizations in July 2015 supplemented an extensive review of these proposals by a panel of experts in April 2015. NSB approval of NSF's selection of an entity to manage and operate the observatory under a new cooperative agreement from January 1, 2017 to December 31, 2022 will be sought in February 2016.

GEODESY ADVANCING GEOSCIENCES AND EARTHSCOPE $13,080,000

+$1,500,000 / 13.0%

Geodesy Advancing Geosciences and EarthScope

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$11.58	$11.58	$13.08	$1.50	13.0%

New mandatory funding ($1.50 million) will support one-time investments to enhance infrastructure at this facility.

Geodesy Advancing Geosciences and EarthScope (GAGE) comprises a distributed, multi-user, national facility for the development, deployment, and operational support of modern geodetic instrumentation to serve national goals in basic research and education in the Earth sciences with a focus on studies of Earth's surface deformation at many scales with unprecedented temporal and spatial resolution. GAGE facilities support fundamental research and discovery on continental deformation, plate boundary processes, the earthquake cycle, the geometry and dynamics of magmatic systems, continental groundwater storage, and hydrologic loading. GAGE is managed and operated for NSF by UNAVCO, Inc., a consortium of 108 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 100 associate members from foreign institutions. GAGE was formed in late FY 2013 from part of the EarthScope program and UNAVCO. In FY 2017, an increase is requested to allow GAGE to continue providing service to the community consistent with that in previous years.

Total Obligations for GAGE

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$11.58	$11.58	$13.08	$11.58	$11.58	$11.58	$11.58	$11.58

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2018.

The ability to determine position with respect to a well-constrained terrestrial reference frame using space geodetic techniques has, over the last three decades, improved to submillimeter capability. Space geodesy applications are extremely broad and expanding to include important societal research on earthquake and tsunami hazards, volcanic eruptions, hurricanes, coastal subsidence, wetlands health, soil moisture, groundwater distribution, and space weather. Applications of geodetic techniques to understanding the complex interplay between climate dynamics, continental ice sheet and mountain glacier dynamics, crustal isostatic adjustments, and sea level change is of foremost relevance to current global issues confronting humanity.

To serve the research needs of the broad earth science community, GAGE is organized under three primary service areas and two special emphasis areas:

Geodetic Infrastructure

- <u>The EarthScope Plate Boundary Observatory (PBO)</u> includes more than 1,100 continuous Global Positioning System (GPS) stations (422 of which transmit data in real-time with subsecond latency) distributed across the U.S., and concentrated on the active plate boundaries in the western contiguous U.S. and southern Alaska. Data recovery for the PBO GPS network typically averages in excess of 95 percent. PBO also includes 75 borehole strainmeters and 78 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (25) and pore pressure sensors (23) are also collocated with the other borehole instruments.

- Global GPS Arrays outside of the PBO footprint are supported by GAGE in partnership with investigators. Nearly 840 continuous GPS observations from around the world are maintained, monitored, and data compiled into the GAGE data system. GAGE supports 62 of the over 250 GPS sites in the National Aeronautics and Space Administration (NASA)-supported Global Navigation Satellite System (GNSS) array that supports satellite orbit and clock corrections and the refinement of the International Terrestrial Reference Frame (ITRF). GAGE is also supporting the development of data distribution systems for a > 100 station Caribbean region GPS and meteorological sensor network (COCONet) to support tectonic, volcano, tropical storm, and sea level change investigations.
- Community GPS receiver and geodetic technology pool includes a pool of over 670 GPS receivers, ancillary equipment, and six terrestrial laser scanners (TLS), which can be used by investigators for short- and long-term deployments on qualified research projects.
- Polar Networks supports GAGE's polar GPS networks in Antarctica (ANET) and Greenland (GNET) and development of specialized GPS monumentation, power, and telemetry solutions for use in harsh environments. GAGE also provides portable campaign deployment geodetic instrumentation, training, and field support for experiments in the polar regions. Additional supplemental funding for these activities is provided through the Division of Polar Programs (PLR).
- Investigator Project Support includes project management, field engineering, and technical support services to plan and execute GPS surveys and permanent station installations. GAGE also maintains a staff focused on geodetic technology equipment testing services to evaluate new geodetic technologies and improve performance for science applications.

Geodetic Data Services

- Geodetic Data Services manages an archive of over 157 terabytes of GPS, laser scanning, Synthetic Aperture Radar (SAR) and borehole geophysical instruments from all GAGE components including EarthScope PBO, global continuous GPS networks, and campaign GPS observations; operates automated and manual systems to ensure the quality of all data stored in the archive; and provides systems to give the national and international research community timely access to these data. The archive of SAR imagery maintained and distributed by GAGE to support interferometric SAR imagery of continuous surface deformation at scales of 100s to 1,000 km is complementary to discrete GPS measurement of displacement. As the U.S. currently has no civilian spaceborne SAR sensor, UNAVCO, as the manager of GAGE, brokers for cost-effective community access to the SAR imagery acquired by foreign SAR satellite systems.

Education and Community Engagement

- The GAGE Education and Community Outreach (ECE) program enables audiences beyond geodesists to access and use geodetic data and research for educational purposes, including technical short courses, student internships, web-based materials, and programs for strengthening workforce development and improving diversity in the geosciences.

Special Emphasis Areas

- Community Activities include scientific and technical workshops that bring together the international seismic community and publications designed to communicate GAGE activities and results to the community.
- External Affairs maintains outreach efforts to policymakers and planning for coordination with the international geodesy community.

Besides its role in providing the observational data essential for basic earth science research, GAGE also plays a significant role providing geodetic infrastructure support to NASA investigators and the international community through activities in maintaining a subset of the Global GNSS Network (GGN); which supports the refinement of the ITRF and corrections to satellite orbits and clocks, all contributing to the capability for millimeter-level geodetic positioning, subtle observations of Earth's time-varying gravity field, and detection of annual millimeter-level changes in sea level.

Commercial surveyors and engineering firms download GAGE facility real-time GPS data daily to support precision positioning. The economic impact of this service to the commercial sector has not been quantified, but is likely substantial.

Management and Oversight

- NSF Structure: The Division of Earth Sciences (EAR), through its Instrumentation & Facilities program (IF), provides general oversight of GAGE to help assure effective performance and administration. The program also facilitates coordination of GAGE programs and projects with other NSF-supported facilities and projects, and with other federal agencies, and evaluates and reviews the performance of UNAVCO in managing and operating GAGE. The Deep Earth Processes section head and division director in EAR provide other internal oversight.
- External Structure: GAGE is managed and operated by UNAVCO, which is incorporated as a non-profit consortium representing 107 U.S. universities and non-profit organizations with research and teaching programs that rely on geodetic technologies for Earth Science research. Each voting member institution of the Consortium appoints a member representative, and these member representatives elect the nine members of the UNAVCO Board of Directors, seven of which are drawn from member institutions, and two directors-at-large. The board members, who serve two-year terms, vet all internal program decisions associated with GAGE management and operation, through consultation with UNAVCO staff and GAGE advisory committees (one for each major GAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of UNAVCO to a renewable two-year term. The president is responsible for UNAVCO operations, all of which are managed through the UNAVCO Corporate Headquarters in Boulder, Colorado.
- Reviews: All major ongoing geoscience facilities routinely undergo mid-award reviews of their management, in addition to peer review of proposals for new or continued support. The formal NSF merit review of the five-year proposal for the GAGE facility took place in 2012 and 2013 and was also the most recent review of UNAVCO. Although the *ad hoc* reviewers and two independent review panels had a number of specific recommendations at the working level for GAGE, overall the review found that GAGE was a critical facility for U.S. and international earth sciences. Furthermore, the reviewers found that UNAVCO is a well-managed and effective organization that has, through its commitment to the collection and open dissemination of the highest quality geodetic data, transformed the discipline of geodesy and its geoscience applications.

Renewal/Recompetition/Termination

The initial cooperative agreement for GAGE began October 1, 2013, and will expire September 30, 2018. In FY 2016, in keeping with the phased integration and recompetition plan presented to the National Science Board in December 2009, NSF intends to solicit proposals for a future facility or facilities to support the earth sciences research and education community currently supported by GAGE and the related Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE). NSF is currently considering the precise form of this solicitation, and any possible future facility/facilities are currently being considered within NSF and through discussions with the GAGE and SAGE support communities.

ICECUBE NEUTRINO OBSERVATORY $7,000,000 +$100,000 / 1.4%

IceCube Neutrino Observatory
(Dollars in Millions)

			Change over FY 2016 Estimate	
FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Amount	Percent
$6.90	$6.90	$7.00	$0.10	1.4%

IceCube is the world's first high-energy neutrino observatory, located deep within the ice cap under the U.S. Amundsen-Scott South Pole Station in Antarctica. With the discovery in 2013 of the first neutrinos from beyond our solar system, the Observatory has demonstrated that it represents a new window on the universe, providing unique data on the engines that power active galactic nuclei, the origin of high-energy cosmic rays, the nature of gamma ray bursts, the activities surrounding supermassive black holes, and other violent and energetic astrophysical processes.

Approximately one cubic kilometer of ice is instrumented with photomultiplier (PM) tubes to detect neutrino-induced, charged reaction products produced when a high-energy neutrino interacts in the ice within or near the cubic kilometer fiducial volume. The energy and arrival direction of high-energy neutrinos ranging in energy from 100 GeV to 10 PeV (1 GeV is 10^9 electron Volts [eV]; 1TeV is 10^{12} eV; and 1 PeV is 10^{16} eV) are derived from the IceCube data stream. The IceCube Collaboration has recently focused on studies of neutrino events with a deposited energy of 1 TeV and above. The "deposited energy" here is the calculated energy that is released within the detector fiducial volume representing an energy level of the incoming neutrino. These high-energy neutrinos can be produced either by the interaction of cosmic rays in the Earth's atmosphere, the so-called atmospheric neutrinos, or in the vicinity of distant astrophysical accelerators like black holes and neutron stars, the so-called astrophysical neutrinos. Astrophysical neutrinos remain the dominant component above 10 TeV.

The IceCube project has transformed one cubic kilometer of natural Antarctic ice into a particle detector. The sensors keep watch for momentary flashes of blue light made by subatomic particles called muons; some are produced in collisions of neutrinos with atomic nuclei inside or near the detector. Since completion in 2010, the IceCube detector has been taking data in its final configuration with an uptime of well over 99 percent. IceCube detects one neutrino every 6 minutes in a background of 2700 cosmic ray muons per second. To handle the high data rates, initial analysis of the data is performed by a cluster of computers housed in a two-story building placed on top of the array. The filtered data is sent over geostationary satellites to the IceCube Research Center at the University of Wisconsin. *Credit: USAP Photo Library, Sven Lidstrom (sic), NSF.*

The Observatory includes a Deep Core Array (DCA) with tightly spaced digital optical modules to detect lower energy neutrinos (down to about 10 GeV), thus opening the door to studies of neutrino oscillation measurements and studies of Weakly Interacting Massive Particles (WIMPs) below 250 GeV. In essence, the DCA closes the energy gap between the IceCube Neutrino Observatory and the Super-Kamiokande detector in Japan, and also allows effective observations of high-energy neutrinos entering from the sky of the southern hemisphere.

Total Obligations for IceCube

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance (GEO)	$3.45	$3.45	$3.50	$3.45	$3.45	$3.45	$3.45	$3.45
Operations & Maintenance (MPS)	3.45	3.45	3.50	3.45	3.45	3.45	3.45	3.45
Total, IceCube	**$6.90**	**$6.90**	**$7.00**	**$6.90**	**$6.90**	**$6.90**	**$6.90**	**$6.90**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2016.

The IceCube Neutrino Observatory is presently led by the University of Wisconsin (UW) and was constructed with support from four countries (U.S., Belgium, Germany, and Sweden). The science collaboration is much broader, currently consisting of 23 U.S. institutions and 24 institutions in eleven other countries (Belgium, Germany, Sweden, Australia, Canada, Denmark, Japan, Korea, New Zealand, Switzerland, and the United Kingdom). NSF's foreign partners contribute a *pro rata* share of operations and maintenance costs based on the number of PhD-level researchers involved.

<u>Management and Oversight</u>

- NSF Structure: Oversight of the IceCube Neutrino Observatory is the joint responsibility of the Geosciences Directorate's Division of Polar Programs (PLR) and the Mathematical and Physical Sciences Directorate's Division of Physics (PHY). Support for operations and maintenance, research and education, and outreach are shared by PLR and PHY, as well as other organizations and international partners. NSF provides oversight through regular site visits by NSF managers and external reviewers.
- External Structure: The UW management structure for IceCube includes leadership by the project's principal investigator supported by the director of operations and two associate directors (one for science and instrumentation and one for education and outreach). A Collaboration spokesperson is selected from the senior international scientific leaders for a two-year term, with an option to be renewed once for at most four consecutive years. At lower levels, project management includes international collaboration representatives, as well as participation by staff at collaborating U.S. institutions. UW has in place an external Scientific Advisory Committee and a Software and Computing Advisory Panel that meet annually and provide written advice to the project. UW leadership, including the Chancellor, provides additional awardee-level oversight.

<u>Operations Costs</u>

Full operations and maintenance in support of scientific research began in FY 2011. The associated costs are and will continue to be shared by the partner funding agencies – U.S. (NSF) and non-U.S. – proportional to the number of PhD researchers involved (currently about 55:45). The current NSF award for operations and maintenance constitutes the bulk of the U.S. contribution to general operation of the facility. In addition, work in support of facility operations is performed by students, postdocs, and senior researchers who are participating in research on the data produced by the Observatory.

NSF support for U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades is provided through the Research and Related Activities (R&RA) account in response to merit-reviewed proposals.

The general operations of South Pole Station, reported in the Polar Facilities and Logistics narrative, also contribute to supporting IceCube. The cost of IceCube operations shown in the table herein includes only those that are project-specific and incremental to general South Pole Station operations. The expected operational lifespan of the IceCube Neutrino Observatory is 25 years, beginning in FY 2011.

Education and Outreach

IceCube provides a vehicle for helping to achieve national and NSF education and outreach goals. Specific outcomes include the education and training of next-generation leaders in astrophysics, including undergraduate students, graduate students, and postdoctoral research associates; K-12 teacher scientific/professional development, including development of new inquiry-based learning materials and use of the South Pole environment to convey the excitement of astrophysics, and science generally, to K-12 students; increased opportunity for involvement of students in international collaborations; increased diversity in science through partnerships with minority institutions; and enhanced public understanding of science through broadcast media and museum exhibits (such as the Adler Planetarium) based on IceCube science and the South Pole environment. NSF supports evaluation and measurement-based education and outreach programs under separate grants to universities and other organizations that are selected following standard NSF merit review.

Renewal/Recompetition/Termination

NSF began a process for re-competition of the operations and maintenance award in late FY 2015. A solicitation for re-competition, conducted in accordance with NSF policy, was issued in July 2015. The present award was extended to allow time for the competition process and now expires in March 2016. A new award is expected to be in place by March 31, 2016.

INTERNATIONAL OCEAN DISCOVERY PROGRAM $48,000,000 / $0 / 0.0%

International Ocean Discovery Program
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$48.00	$48.00	$48.00	-	-

The International Ocean Discovery Program (IODP) began in FY 2014 as the replacement for the Integrated Ocean Drilling Program and the prior Ocean Drilling Program. The IODP represents an international partnership of the scientists, research institutions, and funding organizations of 26 nations to explore the evolution and structure of Earth as recorded in the ocean basins. The program management structure focuses on maximizing facility efficiency, while retaining the intellectual cooperation and exchange with NSF's international partners. NSF, the Ministry of Education, Culture, Sport, Science and Technology (MEXT) of Japan, and the European Consortium for Ocean Research Drilling (ECORD) continue to provide drilling platforms. The IODP platforms provide sediment and rock samples (cores); in-situ monitoring, sampling, and measurement from borehole observatories; shipboard and shore-based descriptive and analytical facilities; down-hole geophysical and geochemical measurements (logging); and opportunities to conduct experiments to determine in-situ conditions beneath the sea floor.

JOIDES Resolution underway for a science expedition, March 10, 2009. *Credit: NSF*

Total Obligations for IODP
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$48.00	$48.00	$48.00	$48.00	$48.00	$48.00	$48.00	$48.00

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only.

Annual operations and maintenance support for operating the *JOIDES Resolution*, the most-used IODP platform, represents NSF's primary contribution to the program. The *JOIDES Resolution* is leased from an offshore drilling contractor under a long-term contract. Another commercial contractor provides down-hole-logging services. Maintaining databases and core repositories, preparing scientific publications emerging from *JOIDES Resolution* IODP expeditions, and management of international program proposal review through the IODP Science Support Office represent additional NSF IODP science integration costs, made minimal to NSF because of international contributions to the program. NSF also provides support for U.S. scientists to sail on IODP drilling platforms and to participate in IODP advisory panels through an associated program. The annual costs for the associated science integration and science support (not included in the table above) are approximately $8.50 million.

The IODP scientific program includes emphasis on the following research themes:

- Climate and Ocean Change: Reading the Past, Informing the Future;
- Biosphere Frontiers: Deep Life, Biodiversity, and Environmental Forcing of Ecosystems;
- Earth Connections: Deep Processes and Their Impact on Earth's Surface Environment; and
- Earth in Motion: Processes and Hazards on Human Time Scales.

The umbrella IODP Forum provides a venue for all IODP entities to exchange ideas and views on the scientific progress of the program. In the current IODP, each drillship is governed by independent facility boards, each unique and optimized for their respective drilling platform. In the case of the *JOIDES Resolution* Facility Board (JRFB), two advisory panels review proposals and provide science and safety advice. A U.S. scientist leads the JFRB, with other members from the scientific community, funding agencies, and the facility operator. The other IODP platforms utilize the JRFB advisory panels for drilling proposal review.

IODP participants include the United States, Japan, ECORD (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and the United Kingdom), Brazil, the People's Republic of China, Korea, India, Australia, and New Zealand, with all participants except Japan providing financial contributions to *JOIDES Resolution* operations. Japan provides program support through substantial investment in *Chikyu* operations, with U.S. and Japanese scientists enjoying reciprocal rights on each drilling vessel and through curation of *JOIDES Resolution* core samples at Japan's Kochi Core Center.

Over 3,500 scientists from 52 nations have participated on Ocean Drilling Program, Integrated Ocean Drilling Program, and International Ocean Discovery Program expeditions since 1985, including approximately 1,500 U.S. scientists from over 150 universities, government agencies, and industrial research laboratories. Samples and data have been distributed to at least 1,000 additional U.S. scientists. Scientists from these groups propose and participate in IODP cruises, are members of the program's advisory panels and groups, and supply data for planning expeditions and interpretation of drilling results.

<u>Management and Oversight</u>

- NSF Structure: The Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO) manages IODP operations of the *JOIDES Resolution* and the IODP Science Support Office under the NSF Ocean Drilling Program (ODP). NSF's ODP is located within the Integrative Programs section, with two program officers dedicated to its oversight. One of the program officers has responsibility for two cooperative agreements supporting *JOIDES Resolution* operations and the IODP Support Office, while the other oversees the cooperative agreement for the IODP U.S. Science Support Program (USSSP).
- External Structure: NSF provides the *JOIDES Resolution* as the light IODP drillship through a cooperative agreement with Texas A&M University. MEXT provides the *Chikyu* as the heavy IODP drillship through the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), while the British Geological Survey manages ECORD drilling contributions through single-use Mission-Specific Platforms. Each entity providing an IODP drilling platform is responsible for sample and data storage, publications, and other science costs associated with the respective platform operations.
- IODP *JOIDES Resolution* operations are determined by the JRFB, utilizing advice and recommendations provided by the Science Evaluation Panel (SEP) and the Environmental Protection and Safety Panel (EPSP). Representation on the panels is determined by contribution level to *JOIDES Resolution* operations and exchange with other facility boards.
- Reviews: Performance of the *JOIDES Resolution* facility is reviewed yearly by an NSF panel, in consultation with the JRFB. Substantive review of management performance regarding *JOIDES Resolution* operations will occur in the third year of the cooperative agreement (FY 2017) to guide

potential renewal or re-competition decisions. Review of scientific progress in broader thematic areas is conducted under the authority of the IODP Forum.

Renewal/Recompetition/Termination

In FY 2013, to facilitate support for drilling proposal review, advisory panel meeting logistics, and other integrative activities for scientists participating in IODP activities (e.g. websites), the IODP Science Support Office was selected at the University of California, San Diego through a competitive process for a five-year (FY 2014- FY 2018) cooperative agreement.

In FY 2014, through a competitive process, Texas A&M University was selected to be the *JOIDES Resolution* operator under a five-year (FY 2015-FY 2019) cooperative agreement. This cooperative agreement contains language encouraging the awardee to facilitate novel partnerships involving support of *JOIDES Resolution* operations between the U.S. scientific drilling community and commercial industry, thereby providing new intellectual opportunities and potential reduction in overall facility cost.

In FY 2015, to facilitate support for U.S. scientists participating on IODP platforms (i.e., salary and travel support) and for U.S. IODP education and outreach efforts, a new cooperative agreement was awarded, after competitive selection, to the Lamont-Doherty Earth Observatory (LDEO) of Columbia University for operation of the U.S. Science Support Program for a five-year period (FY 2015- FY 2019).

The *JOIDES Resolution* operations and science support cooperative agreements contain a provision for annual external review of performance by an independent panel. Intensive mid-award reviews will be conducted for both cooperative agreements and will consider whether they should be extended or re-competed.

LARGE HADRON COLLIDER $20,500,000

+$2,500,000 / 13.9%

Large Hadron Collider

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$18.00	$18.00	$20.50	$2.50	13.9%

The Large Hadron Collider (LHC), an international project at the CERN (the European Organization for Nuclear Research) laboratory in Geneva, Switzerland, is the most powerful particle accelerator ever constructed. It produces the highest energy particle beams ever created, making it the premier facility in the world for research in elementary particle physics. LHC consists of a superconducting particle accelerator, approximately 16.5 miles in circumference, providing two counter-rotating 7 TeV (1TeV=10^{12} electron volts) proton beams. It can also provide colliding beams of heavy ions, such as lead. During 2011 and 2012 ("Run 1"), LHC operated at 4 TeV per beam as a result of a limitation in the electrical connections between the superconducting magnets. After the connections were upgraded during a nearly two-year shutdown, Run 2 began in mid-2015 and will continue through the end of 2018 at 6.5 – 7 TeV per beam, exploring a new energy region not accessible during Run 1.

Four large particle detectors collect the data delivered by LHC. They characterize the reaction products produced in the high-energy proton-proton and heavy ion beam collisions, which are analyzed to investigate the fundamental properties of matter. More than forty international funding agencies provide support for scientists to participate in experiments at the LHC. CERN is responsible for meeting the overall LHC project goals and coordinating international participation. The U.S., through a partnership between the Department of Energy (DOE) and NSF, made major contributions to the construction and operation of two of the largest particle detectors, a Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS), while NSF additionally supports a small number of researchers who participate in the LHC-b detector.

LHC data have resulted in major scientific discoveries. Foremost of these was the July 4, 2012, announcement by the CMS and ATLAS collaborations of the discovery of a particle having properties consistent with the long-sought Higgs boson, a prediction of the Standard Model of particle physics whose existence is a consequence of the theoretical framework describing the origin of the masses of elementary particles. This achievement was recognized by the award of the 2013 Nobel Prize in Physics to Francois Englert and Peter Higgs. On July 14, 2015, the LHC-b experiment reported the discovery of a class of particles known as pentaquarks, a new way to aggregate quarks (the fundamental building blocks of ordinary matter) in a way never before observed. The resumed program of operation at higher energy and higher intensity in 2015 is expected to significantly enhance the chances of more groundbreaking discoveries at the LHC. For example, the LHC program includes searches for particles predicted by a powerful theoretical framework known as supersymmetry, which may provide clues as to how the known forces – weak, strong, electromagnetic, and gravitational – evolved from different aspects of the same "unified" force in the early universe.

Total Obligations for LHC

(Dollars in Millions)

	FY2015 Actual	FY2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$18.00	$18.00	$20.50	$20.50	$20.50	$20.50	$20.50	$20.50

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreements end in December 2016 (CMS) and January 2017 (ATLAS).

A worldwide cyberinfrastructure, the LHC grid, is dedicated to LHC data processing, allowing scientists to remotely access and analyze vast data sets. The U.S. LHC collaboration continues to be a leader in the development and exploitation of distributed computing. The LHC grid and the Tier 2 computing centers funded by NSF enable U.S. universities to access LHC data and computing resources and thus train students in both state of the art science and computational techniques. The distributed computing tools and techniques developed for the LHC are expected to have broad application throughout the scientific and engineering communities.

The May 2014 report[14] of the Particle Physics Project Prioritization Panel (P5) recommended to DOE and NSF that the highest priority strategic goal for the U.S. particle physics within a global context should be continued support for involvement in the LHC program, including a further planned upgrade of the accelerator to very high luminosity (nearly ten times the luminosity of initial operation), for operation commencing in mid-2026, in order to make precision measurements that may reveal new physics beyond the Standard Model. This will necessitate significant enhancements to the detectors in order to exploit this scientific opportunity. NSF is working with the ATLAS and CMS detector collaborations to plan for this. The obligations profile shown in the table above includes additional funding during FY 2017 – FY 2020 to enable research and development and planning that could possibly lead to a major construction upgrade beginning in FY 2020.

Through the participation of young investigators, graduate students, undergraduates, and minority institutions in this international project, LHC serves the goal of helping to produce a diverse, globally oriented workforce of scientists and engineers. Innovative education and outreach activities allow high school teachers and students to participate in this project.

Management and Oversight

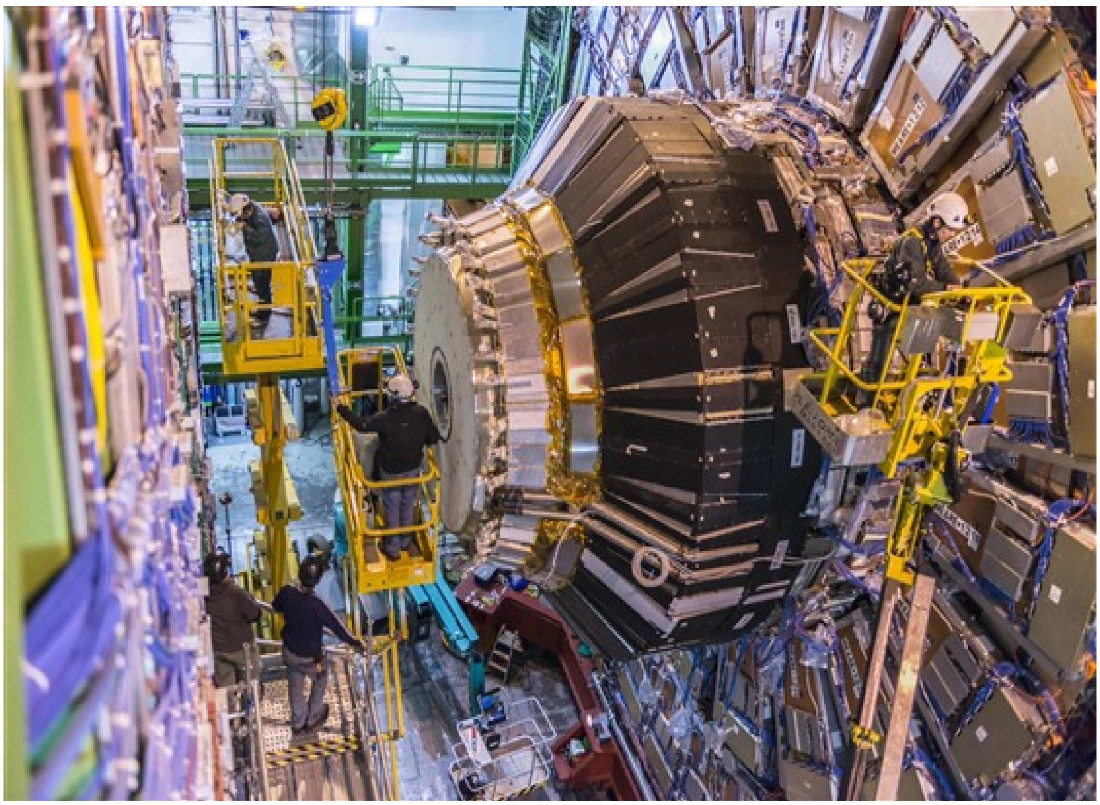
- NSF Structure: A program director in the Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY) is responsible for day-to-day project oversight. The Division of Acquisition and Cooperative Support provides financial and administrative support. An integrated project team with representatives from MPS, the Large Facilities Office, the Office of Budget, Finance, and Award Management, and other experienced program officers contribute to planning activities that may lead to a major construction upgrade.
- External Structure: U.S. program management occurs through a Joint Oversight Group (JOG) created by NSF and DOE. The JOG has the responsibility to see that the U.S. LHC program is effectively managed and executed to meet commitments made under the LHC international agreement and its protocols. NSF operations support is provided through cooperative agreements with Princeton University for US-CMS and with Columbia University for US-ATLAS.
- Reviews: There is one major management/technical review each year with a panel of external, international experts, a follow-up review six months later, as well as bi-weekly telephone reviews by NSF/DOE program directors to monitor progress. NSF and DOE jointly conduct separate external reviews of the detector upgrade activities. The next major management/technical review is scheduled

[14] http://science.energy.gov/~/media/hep/hepap/pdf/May-2014/FINAL_P5_Report_053014.pdf

for April 2016. Two JOG review meetings per year monitor overall program management.

Renewal/Recompetition/Termination

Because of the planned incremental program of enhancements to the accelerator along with parallel upgrades to the detectors, the LHC project is expected to be scientifically productive for at least 15 to 20 more years. It is anticipated that the U.S. ATLAS and CMS collaborations will submit renewal proposals during 2016 for a continuation of support for five years beyond the current agreements, beginning during FY 2017. Through an internal competition process among the research community, the ATLAS collaboration selected Stony Brook University to lead NSF-funded operations in the next cooperative agreement beginning in FY 2017. Princeton University will continue to lead CMS operations.



CMS Detector undergoing maintenance in December 2013. *Credit: CERN.*

LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY — $39,430,000 / $0 / 0.0%

Laser Interferometer Gravitational-Wave Observatory
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate: Amount	Change over FY 2016 Estimate: Percent
$33.00	$39.43	$39.43	-	-

Einstein's theory of general relativity predicts that cataclysmic processes involving extremely dense objects in the universe, such as the collision and merger of two neutron stars or black holes, will produce gravitational radiation. Detection of these gravitational waves is of great importance for fundamental physics, astrophysics, and astronomy. The Laser Interferometer Gravitational-Wave Observatory (LIGO), the most sensitive gravitational-wave detector ever built, comprises two main facilities, one in Livingston Parish, LA and one in Hanford, WA. At each facility, a large vacuum chamber with two 4 kilometer (km) arms joined at right angles houses an optical interferometer. The interferometers are used to measure minute changes in the distances between mirrors at the ends of the arms caused by a passing gravitational wave. The predicted distortion of space caused by a gravitational wave from a likely source is on the order of one part in 10^{21}, meaning that the expected change over the apparent 4-km length is only about 1/1000th the diameter of a proton. The 4 km length for LIGO, the largest for any optical interferometer, was chosen to make the expected signal as large as possible within terrestrial constraints. Looking for coincident signals from both interferometers simultaneously increases LIGO's ability to discriminate a gravitational wave signal from noise.

Components for a third interferometer, initially intended for installation at Hanford as a further tool to discriminate candidate signals from random noise, have been set aside in response to a proposed initiative from the Government of India to establish a gravitational wave observatory there. If realized, this third interferometer would, in addition to increasing noise immunity, greatly enhance LIGO's angular resolution of candidate gravitational wave sources, facilitating follow-up investigations using optical and radio telescopes.

In March 2015, the Advanced LIGO (AdvLIGO) upgrade was completed. Funded through the Major Research Equipment and Facilities Construction (MREFC) account, this activity resulted in the design, fabrication, and installation of improved apparatus expected to enhance LIGO's sensitivity ten-fold. LIGO's operating budget supported the initial commissioning of this apparatus, as well as a program of periodic scientific operation of the LIGO observatories interleaved with continuing engineering studies that enhance operating performance. The overall goal of this activity is to achieve a ten-fold sensitivity improvement by late 2017. Operations support funds basic infrastructure maintenance, analysis and dissemination of data obtained from the interferometers, and

An aerial view of the Livingston, Louisiana LIGO site. *Credit: Caltech/MIT LIGO Laboratory.*

maintenance of computational resources for data storage and analysis. Operations funding also enables complementary research and development, which is expected to lead to further enhancements in operational performance, and education and outreach activities.

In order to meet its cutting-edge performance requirements for the AdvLIGO construction project, substantial connections with industry resulted. Innovations across a diverse range of technologies have led to new techniques with broad applications (for example, preparation of stainless steel for ultra-high vacuum application, adaptive laser beam shaping), and in other cases, have resulted in patents and commercial products (in-vacuum electrical connectors, high power electro-optic modulators).

The LIGO Science Education Center (LIGO SEC), located on the Livingston Observatory site, hosts 50 hands-on inquiry-based learning exhibits and reaches over 15,000 students, teachers, and members of the public each year. These activities benefit from a partnership with Southern University Baton Rouge (SUBR), the San Francisco Exploratorium, the Baton Rouge Area Foundation (BRAF), and other collaborating educational entities. Trained docents from SUBR assist participants and serve as collegiate-age role models for young visitors. LIGO SEC programs are supported both through LIGO's operations cooperative agreement and through grants to SUBR and BRAF.

Total Obligations for LIGO

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$33.00	$39.43	$39.43	$39.43	$39.43	$39.43	$39.43	$39.43

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2018.

The LIGO Scientific Collaboration (LSC), an open collaboration that organizes the major international groups doing research supportive of LIGO, has more than 80 collaborating institutions in 15 countries with more than 900 participating scientists. The LSC plays a major role in many aspects of the LIGO effort, including establishing priorities for scientific operation, data analysis and validation of scientific results, and contributing to instrumental improvements at the LIGO facilities, as well as fostering education and public outreach programs. NSF supports LSC activities at $7.0 to $8.0 million per year, which is provided through regular disciplinary research program funds.

The first scientific operation of both upgraded interferometers commenced in September 2015 and has successfully demonstrated extended operation with a four-fold sensitivity increase relative to the previous LIGO apparatus. By the latter part of 2017, both interferometers are expected to be more than ten times more sensitive than the original LIGO apparatus and will begin gathering more than one year of concurrent data.

Acting on the advice of a 2014 external review panel that assessed LIGO’s computing strategy, a no-cost extension of the AdvLIGO MREFC project was approved by NSF to enable the project to purchase computing hardware immediately, or prior to when needed, in order to benefit from continuing technical innovation and price/performance advances. Consequently, the last computing purchases through MREFC construction funding will be deferred until mid-2017.

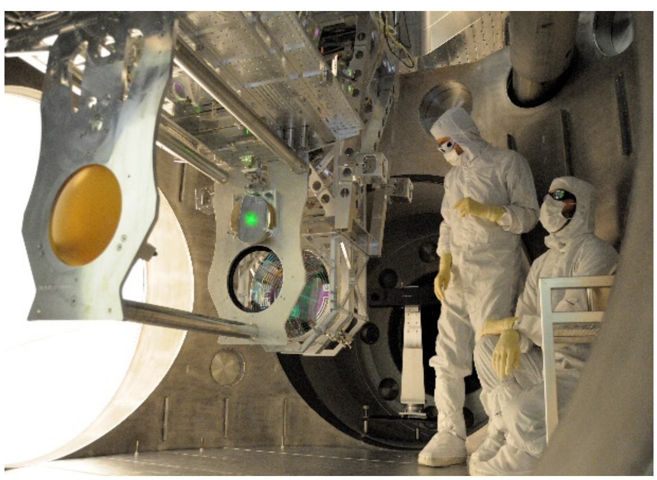
NSF has determined operating budget requirements by assessing cost data from initial LIGO interferometer operation and scaling appropriately to reflect the increased support needed to support the more complex AdvLIGO apparatus. NSF continually assesses the appropriate level of financial support by monitoring actual expenditures contained in quarterly financial reports from LIGO and through annual external reviews of operation.

Management and Oversight

- NSF Structure: NSF oversight is coordinated internally by the LIGO program director in the NSF Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY), who also chairs the PHY AdvLIGO Integrated Project Team (IPT), comprised of the Physics Division Director, MPS Facilities Coordinator, staff from the Large Facilities Office, Office of General Counsel, Office of Legislative and Public Affairs, Office of International Science and Engineering, and program directors from elsewhere in NSF.
- External Structure: LIGO is managed by California Institute of Technology under a cooperative agreement. The management plan specifies significant involvement by the user community, represented by the LSC, and collaboration with the other major gravitational-wave detector activities in Asia, Europe, and Australia. External peer-review committees organized by NSF help provide oversight through annual reviews.
- Recent Reviews:
  - LIGO and AdvLIGO Computing Review, May 2014
  - LIGO Annual Review and AdvLIGO Interim Review, June 2014
  - LIGO and AdvLIGO Computing Review, May 2015
  - LIGO Annual Review and AdvLIGO Completion Review, June 2015
  - An annual review of LIGO operations is planned for mid-2016

Renewal/Recompetition/Termination

LIGO began operating under a five-year cooperative agreement in early FY 2009, which ran concurrently with the AdvLIGO MREFC project. Following approval by the National Science Board in August 2013, the cooperative agreement was renewed at the beginning of FY 2014 for five additional years, overlapping the conclusion of AdvLIGO construction and the start of commissioning and scientific operation. NSF will perform a rigorous review of LIGO prior to the expiration of the current operating award to determine whether it is in the best interest of U.S. science and engineering to re-compete that award. The projected lifetime of the LIGO facility was originally 20 years. Infrastructure refurbishments recently accomplished or planned during the current award will extend the facility life by an additional 15 to 20 years, to beyond 2030.



Installation of the green (532nm) Arm Length Stabilization(ALS) subsystem for AdvLIGO. *Credit: Caltech/MIT LIGO Laboratory.*

NATIONAL HIGH MAGNETIC FIELD LABORATORY $35,780,000 +$13,000,000 / 57.1%

National High Magnetic Field Laboratory
(Dollars in Millions)

			Change over FY 2016 Estimate	
FY 2015 Actual[1]	FY 2016 Estimate[1]	FY 2017 Request	Amount	Percent
$35.92	$22.78	$35.78	$13.00	57.1%

[1] Forward funding from FY 2013 to FY 2014 reduced the FY 2015 Request by just over $9.0 million to $24.04 million. Subsequent forward funding of $11.88 million from FY 2015 to FY 2016 reduced the amount needed in FY 2016.

The National High Magnetic Field Laboratory (NHMFL) is operated by Florida State University (FSU), University of Florida (UF), and Los Alamos National Laboratory (LANL). NHMFL develops and operates high magnetic field facilities that scientists and engineers use for research in condensed matter and material physics, materials science and engineering, chemistry, biology, biochemistry, neuroscience, energy, and the environment. It is the world's premier high magnetic field laboratory with a comprehensive collection of high-performing magnet systems and extensive support services. The facilities are available to all qualified scientists and engineers through a peer-reviewed proposal process. Users number about 1,300 per year, including faculty and staff at the three host institutions.

The laboratory is an internationally recognized leader in magnet design, development, and construction, including the development of new superconducting materials. Many of the unique magnet systems were designed, developed, and built by the Magnet Science and Technology (MS&T) Division of NHMFL. Since 2012, the laboratory has held the world's record for the highest nondestructive, pulsed magnetic field at 100.75 tesla. The 45 tesla hybrid magnet currently provides the highest steady-state magnetic fields in the world. Both magnets enable scientists to get new insights into the electronic structures of novel materials such as graphene, topological insulators, high temperature superconductors, and more. MS&T works with industry and other international magnet laboratories on a variety of technology projects. These include design and construction of high field magnets, component development, coil fabrication, cryogenics, system integration, and testing.

A $15.0 million award funded by the American Recovery and Reinvestment Act of 2009 through the NSF Directorate for Mathematical and Physical Sciences, Division of Chemistry (MPS/CHE) enabled the purchase of a 21 Tesla magnet for the construction of a Fourier Transform Ion Cyclotron Resonance (FT-ICR) spectrometer. The 21 Tesla magnet, the heart of the spectrometer, was installed in June 2014 and has been running continuously. The FT-ICR instrument opened for user operations in October 2015. The 21 Tesla FT-ICR is unprecedented in sensitivity and selectivity, capable of analyzing chemical samples of great complexity, such as biological fluids, biofuels, and raw and weathered petroleum. This will impact areas such as chemistry, molecular biology, and earth science.

The FY 2017 Request will allow the facility to continue operations, focus on magnet development, and strengthen education, training, user support, and in-house research. NSF provided $11.88 million in forward funding in FY 2015, thus reducing the level needed in FY 2016. The FY 2017 Request is consistent with the originally planned funding level. A potential impact of this investment is the successful construction of an all superconducting magnet that would make high magnetic fields attainable at lower operating costs than current technology. This would open the door for many laboratories to access high magnetic fields and could be transformational in many research areas, particularly when combined with other probes such as X-rays, neutrons, or terahertz radiation. Another example of a potential breakthrough is in new imaging techniques for studying the brain. Currently Magnetic Resonance Imaging (MRI) and functional MRI have been based on imaging proton spin density and intrinsic tissue relaxation rates. With higher magnetic field strengths, NHMFL is pushing to use other nuclei. New insights into mapping the brain and neurochemistry may result.

Total Obligations for NHMFL

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate[1]	FY 2017 Request	ESTIMATES[2] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$35.92	$22.78	$35.78	$35.78	$35.78	$35.78	$35.78	$35.78

[1] Forward funding of $11.88 million in FY 2015 reduced the amount needed in FY 2016.

[2] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2017.

NHMFL collaborates with more than 60 private sector companies as well as national laboratories, including those supported by the Department of Energy (DOE), such as Oak Ridge National Laboratory, which hosts the Spallation Neutron Source, and Argonne National Laboratory, which hosts the Advanced Photon Source. International collaboration is strong; NHMFL delivered and commissioned a 26 Tesla series connected hybrid resistive/superconducting magnet to the Helmholtz-Zentrum Berlin (HZB), where it will be used for neutron scattering experiments. Collaborations also exist with the International Thermonuclear Experimental Reactor (ITER) in France, and national magnet labs in France, the Netherlands, Germany, and China.

NHMFL provides a unique interdisciplinary learning environment. The Center for Integrating Research and Learning at NHMFL conducts education and outreach activities, which include a Research Experience for Undergraduates (REU) program, summer programs for teachers, a summer camp for middle school girls, and activities to raise the scientific awareness of the general public.

Management and Oversight

- NSF Structure: NHMFL is supported by the MPS Division of Materials Research (MPS/DMR), with the DMR program director as the primary contact for most of the laboratory. The MPS Division of Chemistry (MPS/CHE) supports the Fourier Transform Ion Cyclotron Resonance (FT-ICR) Laboratory, which is overseen by a CHE program director.
- External Structure: A consortium of FSU, UF, and LANL operates NHMFL under a cooperative agreement. FSU, as the agreement signatory, is responsible for administrative and financial oversight and for ensuring that lab operations are consistent with the cooperative agreement. The principal investigator, the NHMFL director, reports to the FSU Vice President for Research. Four senior faculty members are co-principal investigators. The NHMFL director receives guidance primarily from the NHMFL executive committee, NHMFL science council, and NHMFL diversity committee and recommendations from an external advisory committee and the users' executive committee. An in-depth review of all NHMFL safety procedures and protocols was initiated in response to a serious safety incident in October 2015. An independent Investigative Committee (IC) was established by the FSU Vice President for Research to find the root cause of the incident and to provide recommendations according to the best practices on Environmental, Health, and Safety (EHS).
- NSF initiated a community study through the National Research Council on opportunities in high magnetic field research. The 2013 report "High Magnetic Field Science and Its Application in the United States"[15] was presented to the National Science Board (NSB) in May 2014. Public town halls were held at several professional meetings by both DMR and CHE. The report will inform future plans

[15] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states

for investments in this area, providing several recommendations with respect to scientific priorities and new magnet developments.

- Reviews: NSF monitors annual plans and reports including user metrics and conducts monthly teleconferences with the director. NSF conducts annual external reviews, which assess the user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and new facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. Recent and upcoming reviews include:
    - Business Systems Review, January 26-28, 2015.
    - Annual site review by external panel of site visitors, June 3-4, 2015.
    - In fall 2015, NSF-DMR program directors visited all three NHMFL sites (FSU and UF sites in October 7-8, 2015 and the pulsed field facility in October 28-29. 2015).
    - Renewal proposal site visit, fall 2016.

Renewal/Recompetition/Termination

After a comprehensive review in FY 2012, NSB authorized a five-year award and up to $168,380,000 for the operation and management of NHMFL. The end date of the current award is December 31, 2017. In May 2015, NSB authorized the NSF Director, at her discretion, to waive re-competition and to provide for NSB consideration a renewal award. A proposal will be reviewed starting in summer 2016 for a potential award renewal beginning in FY 2018.

NATIONAL NANOTECHNOLOGY COORDINATED INFRASTRUCTURE — $15,460,000 / $0 / 0.0%

National Nanotechnology Coordinated Infrastructure

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate: Amount	Change over FY 2016 Estimate: Percent
$15.02	$15.46	$15.46	-	-

Over the past decade (2004-2015), the National Nanotechnology Infrastructure Network (NNIN) has enabled major discoveries, innovations, and contributions to education and commerce. It has provided researchers from academia, small and large companies, and government with open access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering, and technology. Building on this prior investment, NSF conducted and completed a competition for the new National Nanotechnology Coordinated Infrastructure (NNCI), as the successor program to NNIN. The NNCI represents a new model in which NSF selects and manages each university site in the network rather than a single lead institution with collaborating partners as in the previous NNIN. The new model allows for more competition and flexibility in awardee selection and management, and provides more agility in addressing emerging user facility needs in nanoscale research and education. A coordinating office will be selected competitively from among the selected sites in early FY 2016 to enhance their impact as a national infrastructure of user facility sites.

Total Obligations for NNCI

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$15.02	$15.46	$15.46	$15.46	$15.46	$15.46	$15.46	$15.46

[1] Outyear funding estimates are for planning purposes only. FY 2015 is the first year of funding for the program.

Fifty-five proposals were received in response to the NNCI solicitation NSF 15-519. After a two-stage review process of mail/panel review and virtual reverse site review, a total of 16 NNCI site awards to universities for user facilities were made as cooperative agreements in FY 2015. Awards were selected by considering the technical merits and emerging capabilities in nanoscale research and education, and the geographic distribution of recommended sites. Among the 16 NNCI sites, eight are new, and eight have served previously as NNIN sites. Nine of the awards include at least one additional regional partner institution as subawardees. The 16 sites are located in 15 states and involve 27 universities across the Nation. Three of the award sites are in Experimental Program to Stimulate Competitive Research (EPSCoR) states, one partner institution is a Historically Black College and University (HBCU), and two partner institutions are community colleges. A provisional website for the NNCI sites and community has been established at http://nnci.net.

NSF awards to individual sites range from $500,000 to $1.60 million per year. Total five-year funding for the NNCI program is $76.86 million and is provided by all seven NSF directorates, the Office of International Science and Engineering, and the EPSCoR program. In the past, NSF supported the NNIN at a similar total annual funding level.

The individual NNCI award sites have autonomy in their operation and management but will be required to act in concert with the coordinating office. The overall collection of sites and their capabilities provide users with cost-effective access both to the specialized tools, processes, and expertise for complex multi-step fabrication at the nanoscale level for structures, materials, devices, and systems, as well as to the associated instrumentation for nanoscale characterization, analysis, and probing. The program makes these capabilities broadly available to the Nation's researchers in academia, industry, and government to help catalyze new discoveries in science and engineering and to stimulate technological innovation. The individual award sites are intended to support a rich user base with broad accessibility and affordable user fee structure. NSF funds leverage those of university and other resources to grow the numbers of external users, including those from companies and academia. Sites embrace a culture of open access to researchers for any research project of merit, with protection of intellectual property, and mechanisms for encouraging non-traditional users from diverse disciplines. They also have an organizational structure that facilitates coordination of complex process steps and tools for integrated tasks and acceptance of experimental risks associated with non-standard processes and materials.

The broad spectrum of domain capabilities in this coordinated program encompass: physical-, chemical-, and biological-based nanostructures, materials, devices, and systems; electronic, optical, photonic, magnetic, mechanical, thermal, chemical, bioengineering, biomedical, and fluidic nanodevices and systems; nanoscale building blocks and nanostructured materials, composites, coatings, and surfaces; geophysical, geochemical, and environmental nanostructures and processes; synthetic biology, and fabrication in soft matter including biological interfaces; heterogeneous integration of complex, three-dimensional nanoscale systems to create new functionality; hierarchical design and fabrication to build nanoscale systems across multiple dimensional scales, including modeling and simulation tools that complement and support these activities; prototyping, process integration, and testing of manufacturing concepts, including high-speed roll-to-roll fabrication processes.

Nanotechnology facilities provide unique opportunities to infuse innovative education with research at the frontiers of the field. Award sites are providing focused strategies for integrating pioneering science and engineering with education, including plans for assessing effectiveness and spreading promising practices. Sites having particular expertise in the social and ethical implications of nanotechnology have integrated study and dissemination of those aspects into their proposals that can leverage their user community base, which relate to the capabilities of their respective user facilities.

Management and Oversight

- NSF Structure: Post-award oversight is performed under the guidance of the NSF lead program officer and directorate working group members to monitor progress of the award and award accomplishments.
- External Structure: The coordinating office (CO) is currently being competed through externally reviewed supplemental requests from among the interested awarded sites. The CO director will be a key individual for developing management strategies and operational plans in concert with the site directors of the individual user facilities, and will serve as a principal contact person with NSF. The CO will establish a comprehensive web portal to ensure close linkage among the individual facility websites to present a unified interface to the user community of overall tools, instruments, and capabilities. The portal will help coordinate and disseminate best practices for national-level education and outreach programs, as well as instruction across sites in social and ethical implications of nanotechnology, including issues related to environment, health, and safety. The CO will harmonize capabilities for modeling and simulation across sites and interaction with NanoHUB of the NSF-supported Network for Computational Nanotechnology (NCN). It will establish uniform methods for assessment and quantifiable metrics of site performance and impact. It will also engage all sites in a planning process to explore emerging areas of nanoscale science, engineering, and technology that can lead to new research opportunities and future growth of the external user base. The CO is expected to be funded at $700,000 annually.
- Reviews: Reviews will be conducted through annual reverse site visits at NSF; on-site reviews, particularly for the larger funded sites, may be held. A Business Systems Review will be held once

within the five-year period of the award. The awardees will submit comprehensive annual project reports to NSF in advance of each annual review. The annual project reports will contain a program plan and budget for the next year's funding increment. Each annual review of a site will focus on the quality of performance and management under the cooperative agreement. Data collection will be consistent with NSF policies for information collection.

Renewal/Recompetition/Termination

- The initial NNCI award is for five years and may be renewed once for an additional five years, subject to external merit review. Limited new competitions may be held, based on availability of funds, to address critical needs in nanotechnology or to replace non-performing sites or the CO.

NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY **$24,500,000**
+$500,000 / 2.1%

National Superconducting Cyclotron Laboratory
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$23.00	$24.00	$24.50	$0.50	2.1%

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) is a university-based national user facility. With two linked superconducting cyclotrons, K500 and K1200, it is the leading rare isotope research facility in the U.S. and is among the world leaders in heavy ion nuclear physics and nuclear physics with radioactive beams. NSCL funding also supports the MSU faculty and staff research program.

NSCL scientists employ a range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Applications of NSCL-conducted research benefit society in numerous areas, including new tools for radiation treatments of cancer patients, assessments of health risks to astronauts, and homeland security. K500 was the first cyclotron to use superconducting magnets, and K1200 is the highest-energy continuous beam accelerator in the world. Through the Coupled Cyclotron Facility (CCF), heavy ions are accelerated by the K500 and then injected into the K1200, enabling the production of rare unstable isotopes at much higher intensities. The laboratory has commissioned an MSU-funded reaccelerator facility (ReA3) that enables experiments at very low energies – a domain of particular interest to nuclear astrophysics. This is the only facility in the world to provide radioactive beams in this energy regime. Two experiments with the ReA3 facility were completed in October 2015.

Scientists at NSCL work at the forefront of rare isotope research. They make and study atomic nuclei that cannot be found on Earth and perform experimental research using beams of unstable isotopes to extend our knowledge of new types of nuclei, many of which are important to an understanding of stellar processes. Research activities include a broad program in nuclear astrophysics studies, the studies of nuclei far from stability using radioactive ion beams, and studies of the nuclear equation of state. In addition, research is carried out in accelerator physics.

Graduate students Joshua Bradt and Eric Lunderberg check the diagnostic station on the ReA3 beamline at NSCL. *Credit: NSCL.*

NSCL supports and enhances doctorate graduate education and post-doctoral research experiences. About 10 percent of all doctorates granted in nuclear physics in the U.S. are based on research at NSCL. The lab also provides research experiences for undergraduate students, K-12 students, and K-12 teachers.

The coupled cyclotron facility supports a broad experimental program. The mix of experiments is determined by beam use proposals. An external program advisory committee selects the best proposals at a typical success rate of about 50 percent, with constraints on beam availability. The science output of NSCL is driven by these experiments, with most running five to ten days.

Total Obligations for NSCL

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$23.00	$24.00	$24.50	$24.50	$24.50	$24.50	$24.50	$24.50

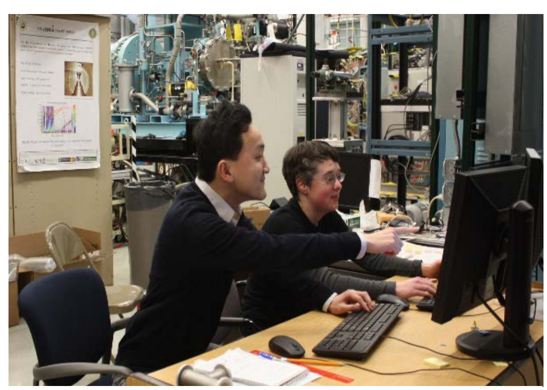
[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September

Management and Oversight

- NSF Structure: MSU operates NSCL under a cooperative agreement with NSF. NSF oversight is provided through annual site visits by the cognizant program officer of the NSF Directorate for Mathematical and Physical Sciences, Division of Physics (MPS/PHY) and other staff, accompanied by external experts. The NSF program officer monitors lab operations and plans through monthly phone conferences with the NSCL director. NSF uses the annual site visit reviews to assess the user program, operations, maintenance, facility efficiency, national and international research developments, and in-house research programs.
- External Structure: MSU provides additional support. NSCL is managed by a director and three associate directors (for experimental research, education & outreach, and operations) as well as a chief scientist. The director has authority to appoint associate directors and designate responsibilities, notifying NSF of changes. NSCL's research program is guided by a program advisory committee of external experts as well as an in-house expert and the chairperson of the NSCL user group. Opportunities for proposal submission occur every nine to twelve months so that the beam hour backlog is no longer than one year. Optimally the laboratory can provide about 5000 beam hours to the scientific community each year, with actual output depending upon facility reliability factors and available funds.
- Reviews:
  - In FY 2016, a 5-year review looked at results and achievements related to intellectual merit and broader impacts for FY 2012 – FY 2015 as well as made an in depth review of proposed research, operations, and maintenance funding for FY 2017 – FY 2021.
  - In early FY 2017, an annual review is tentatively planned.

Renewal/Recompetition/Termination

MSU has submitted a proposal for a five-year renewal award for the research program and operation of NSCL from FY 2017 through FY 2021. The proposal has been merit reviewed and a new cooperative agreement is under consideration. NSCL will transition to the new Facility for Rare Isotope Beams (FRIB), which is being built by the Department of Energy (DOE) on the NSCL site. FRIB is scheduled to become operational in FY 2022 and will use much of the NSCL beamlines, instrumentation, and general infrastructure. NSF anticipates ending support for the operations component of NSCL when CCF operations cease so that FRIB can be integrated into the NSCL beamlines and become operational. MSU will be the performing institution under a cooperative agreement with DOE for the future FRIB. To facilitate interagency planning and coordinate the transition from the NSF-funded NSCL to the DOE-funded FRIB, a Joint Oversight Group (JOG) of DOE and NSF personnel has been meeting since 2010. DOE and NSF will coordinate transfer of facility stewardship as it transitions from NSCL to FRIB. NSF will continue to support individual investigators carrying out research at the new FRIB.



Postdoc Kenjiro Miki and Assistant Professor Ulrike Hager at the JENSA (Jet Experiments in Nuclear Structure and Astrophysics) station. *Credit: NSCL.*

NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE $12,500,000 $0 /0.0%

Natural Hazards Engineering Research Infrastructure

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$18.24	$12.50	$12.50	-	-

The Natural Hazards Engineering Research Infrastructure (NHERI) is the next generation of NSF support for a multi-user, natural hazards engineering research facility, replacing the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). NEES was established by NSF as a distributed, multi-user, national research infrastructure for earthquake engineering research through support of a facility construction phase during 2000-2004, followed by support of an operations phase for research, innovation, and education activities from October 2004 through September 2014. NEES was supported by NSF during FY 2010–2014 through a cooperative agreement with Purdue University. The NEES infrastructure included 14 earthquake engineering experimental facilities and an integrative cyberinfrastructure. During FY 2015, NSF's cooperative agreement with Purdue University was extended to continue support for cyberinfrastructure operations during the NSF open competition to establish NHERI via program solicitations NSF 14-605 and NSF 15-598.

Beginning in FY 2016, NHERI will be operated for five years as a distributed, multi-user, national research facility, aiming to provide the natural hazards engineering research community with access to research infrastructure (earthquake and wind engineering experimental facilities, cyberinfrastructure, computational modeling and simulation tools, and research data), coupled with education and community outreach activities. Building upon NEES, NHERI will enable new discovery and knowledge through enhanced capacity to test and derive more comprehensive, complete, and accurate models of how constructed civil infrastructure responds to earthquake and wind loading. This will enable the design of new methodologies, modeling techniques, and technologies for earthquake, windstorm, and multi-hazard mitigation. Research conducted using NHERI will support the National Earthquake Hazards Reduction Program and the National Windstorm Impact Reduction Program.

NHERI will be established by NSF through up to eleven individual cooperative agreements and will consist of the following four components:

- Network Coordination Office (NCO);
- Cyberinfrastructure (CI) Operations;
- Computational Modeling and Simulation Center (SimCenter); and
- Eight Experimental Facilities (EF), including a new post-disaster, rapid response research facility.

As the outcome of the NSF 14-605 competition, eight awards were made for NHERI in FY 2015:

- Cyberinfrastructure, at the University of Texas at Austin (http://DesignSafe-Ci.org)
- Twelve-Fan Wall of Wind, at Florida International University
- Large-Scale, Multi-Directional, Hybrid Simulation Testing Capabilities, at Lehigh University
- Large Wave Flume and Directional Wave Basin, at Oregon State University
- Geotechnical Centrifuges, at the University of California, Davis
- Large, High-Performance Outdoor Shake Table, at the University of California, San Diego
- Boundary Layer Wind Tunnel, Wind Load and Dynamic Flow Simulators, and Pressure Loading Actuators, at the University of Florida, and

- Large, Mobile Dynamic Shakers for Field Testing, at the University of Texas at Austin

In August 2015, NSF issued solicitation NSF 15-598 to compete the final three components of NHERI: the Network Coordination Office, Computational Modeling and Simulation Center, and Post-Disaster, Rapid Response Research Facility. Awards will be completed in spring 2016.

The NCO awardee will serve as the national and international scientific leader, community focal point, and network-wide coordinator for NHERI governance and community-building activities. Key activities will include convening the governance groups, working with the Council of Awardees to develop consensus-based policies and procedures for NHERI and the annual Council work plan, implementing the facility scheduling protocol to provide user access to the EFs, leading development of community science plans, running NHERI-wide education and community outreach programs, and building strategic partnerships.

The 12-fan Wall of Wind at Florida International University (FIU), one of the NHERI experimental facilities, will enable better engineering against tornadoes, hurricanes, and other windstorms. *Photo Credit: Courtesy of FIU.*

The CI awardee will serve as the integrator for enabling NHERI to be a virtual organization for the natural hazards engineering community, by providing an array of information, resources, and services, including the definitive NHERI website, data repository, software service delivery platform with computational modeling, simulation, and educational tools, collaboration tools, access to computing resources, and user training and support. The CI awardee will establish and implement a NHERI-wide cybersecurity plan with all NHERI awardees.

The SimCenter awardee will develop a portfolio of computational modeling and simulation software and educational modules that reflects a balance of community-prioritized, new capabilities for earthquake, wind, and multi-hazard engineering research and education. The SimCenter awardee will deliver this portfolio to the CI awardee for integration onto the CI awardee’s software service delivery platform.

EF awardees will provide well-maintained and fully functioning facilities, services, and staffing to enable earthquake engineering, wind engineering, and post-disaster, rapid response research requiring experimental work and data collection. Experimental data generated by EF resources and their users will be archived and maintained in the publicly accessible NHERI data repository. The awardees and the natural hazards engineering community will work together, through governance and awardee activities, to establish a shared vision for NHERI, set natural hazards engineering research and education agendas and priorities, and make NHERI a value-added and productive research infrastructure.

Along with direct operations and maintenance support for NHERI awardees, NSF will provide separate support for research to be conducted at the NEHRI experimental facilities through ongoing research and education programs. The support for such activities primarily will be provided through the existing Engineering for Natural Hazards (ENH) research program in the Civil, Mechanical and Manufacturing Innovation (CMMI) division in the Directorate for Engineering (ENG). The ENH program supports basic research in multi-hazard engineering involving experimental and computational simulations at the NHERI facilities, addressing important challenges in multi-hazard mitigation for constructed civil infrastructure.

With the aim of integrating research and education, NHERI will engage students through on-site use of experimental facilities, telepresence technology, experimental and analytical data, and computational resources. Coordinated by the NCO awardee, NHERI awardees will also run an annual Research Experiences for Undergraduates (REU) program and a Summer Institute.

Total Obligations for NHERI
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$18.24	$12.50	$12.50	$12.50	$12.50	$12.00	$12.00	$12.00

[1] Outyear funding estimates are for planning purposes only. FY 2015 is the first year of funding for the program.

Management and Oversight

- NSF Structure: The NSF program manager for NHERI is located within ENG/CMMI. The Deputy Director of the Large Facilities Office in the Office of Budget, Finance and Award Management provides advice and assistance.

- External Structure: Each NHERI awardee is led by a principal investigator (PI), who will be responsible for the overall award operations. The NCO awardee will coordinate NHERI and be responsible for convening NHERI governance. Governance will be comprised of the following groups: (a) a Council, which consists of the PI of each NHERI award, to provide collective and coordinated leadership for NHERI as a national facility, (b) Network Independent Advisory Committee, with diverse representation from the broad scientific and engineering communities served by NHERI, to provide independent external guidance and advice to the Council, (c) User Forum, consisting of representatives from the broad scientific and engineering communities served by NHERI, and (d) Council-identified committees, comprised of internal awardee staff and/or users, to advise the Council on community priorities and needs for NHERI.

- Reviews: NSF will provide oversight to NHERI awardees through cooperative agreements. Individual and joint awardee operations and activities will be reviewed through quarterly and annual project reports submitted by awardees and site visit reviews conducted by NSF. Site visit reviews will include the following:
  - Site visit merit reviews:
    - Annually for NCO, CI, and SimCenter awardees;
    - For EF awardees: Up to four facilities will receive site visits each year.
  - NSF Business Systems Review, for each awardee, with the review to be conducted within the first two years of the award.

Renewal/Recompetition/Termination

- In FY 2010, NSF supported two studies to assess the need for earthquake engineering experimental and cyberinfrastructure facilities beyond 2014, as described in the Dear Colleague Letter NSF 10-071.[16] One study, a workshop held by the National Research Council on the Grand Challenges in Earthquake Engineering Research, was completed in FY 2011 and the second study was completed in FY 2012. These studies provided input to NSF for the determination of support for future earthquake engineering research infrastructure beyond FY 2014. The plan to support a smaller "second generation" NEES (NEES2) during FY 2015-FY 2019 was presented to the National Science Board at their July 2012 meeting and described in the Dear Colleague Letter NSF 12-107.[17] The plan would result in a lower

[16] http://nsf.gov/pubs/2010/nsf10071/nsf10071.jsp
[17] www.nsf.gov/pubs/2012/nsf12107/nsf12107.jsp

annual operations budget, reflected in the $8.0 million reduction from FY 2014 in the FY 2015 Budget Request, from $20.0 million to $12.0 million, and allow additional investments to be made in earthquake engineering research.

- In 2012, the National Institute of Standards and Technology and NSF jointly supported a workshop that led to a roadmap report for measurement science research and development for windstorm and coastal inundation impact reduction, which was published in January 2014.[18]
- In February 2013, NSF released solicitation NSF 13-537 in an effort to compete and operate NEES2 for FY 2015-FY 2019. Based on the merit review of proposals submitted under NSF 13-537, NSF made no award.
- Based on the above studies and report, NSF established the plan for NHERI in FY 2014. This led to the release of solicitations NSF 14-605 and NSF 15-598 to establish NHERI through two competitions. NHERI operations awards are supported for a five-year period with an option for an additional five years. During this period, the NCO awardee will be responsible, working with the natural hazards engineering research and education community, to develop a five-year NHERI Science Plan. ENG will separately support the development of a post-NHERI decadal science plan for natural hazards engineering research, education, and research infrastructure. NSF will use this decadal science plan as input for natural hazards engineering research infrastructure support beyond 2019.

[18] www.nist.gov/customcf/get_pdf.cfm?pub_id=915541

OCEAN OBSERVATORIES INITIATIVE $50,000,000 -$5,000,000/ -9.1%

Ocean Observatories Initiative

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$55.00	$55.00	$50.00	-$5.00	-9.1%

The Ocean Observatories Initiative (OOI) began in FY 2009 as a Major Research Equipment and Facilities Construction (MREFC) project. In FY 2016, OOI transitioned from the MREFC construction effort to the operations & maintenance phase.

OOI is a networked ocean-focused research observatory with arrays of instrumented buoys, profilers, gliders, and autonomous vehicles within different open-ocean and coastal regions, as well as a cabled array of instrumented platforms and profilers on or above the seafloor over the Juan de Fuca tectonic plate. This networked system of instruments, platforms, and arrays enables researchers to examine complex, interlinked physical, chemical, biological, and geological processes operating throughout the coastal regions and to investigate a spectrum of phenomena and processes including episodic, short-lived events (meteorological, tectonic, volcanic, geological, geophysical, and ecological), and more subtle, long-term changes and emergent phenomena in ocean systems (circulation patterns, climate change, ocean acidity, geophysical events, and ecosystem trends).

The OOI facility provides the public, educators, students, and researchers with: (1) OOI long-term time series data sets (raw data and metadata are processed via conventional algorithms and quality control methods); (2) an in-situ ocean laboratory capability to allow OOI users to submit proposals for development and application of new technologies by connecting their instruments or concepts to the OOI network; and (3) OOI tools that will support undergraduate classroom applications of the OOI, as well as public outreach through informal education. The OOI delivers all data/metadata and education tools to the public via the internet at www.oceanobservatories.org.

The overarching scientific themes of the OOI span six multi-disciplinary domains, and each theme incorporates a multitude of research questions.

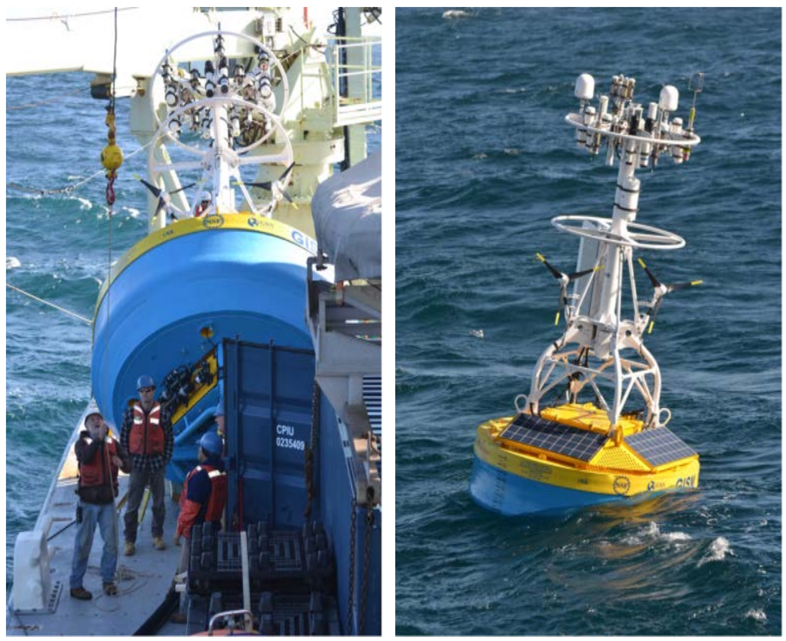
- *Ocean-Atmosphere Exchange*. Quantifying the air-sea exchange of energy and mass, especially during high winds, is critical to providing estimates of energy and gas exchange between the surface and deep ocean, and improving the predictive capability of storm forecasting and climate-change models.
- *Climate Variability, Ocean Circulation, and Ecosystems*. As both a reservoir and distributor of heat and carbon dioxide, the ocean modifies climate, and is also affected by it. Understanding how climate variability will affect ocean circulation, weather patterns, the ocean’s biochemical environment, and marine ecosystems is a compelling driver for multidisciplinary observations.
- *Turbulent Mixing and Biophysical Interactions*. Mixing occurs over a broad range of scales and plays a major role in transferring energy, materials, and organisms throughout the global ocean. Mixing has a profound influence on primary productivity, plankton community structure, biogeochemical processes (e.g., carbon sequestration) in the surface and the deep ocean, and the transport of material to the deep ocean.
- *Coastal Ocean Dynamics and Ecosystems*. Understanding the spatial and temporal complexity of the coastal ocean is a long-standing challenge. Quantifying the interactions between atmospheric and terrestrial forcing, and coupled physical, chemical, and biological processes, is critical to elucidating

the role of coastal margins in the global carbon cycle, and developing strategies for managing coastal resources in a changing climate.

- *Fluid-Rock Interactions and the Subseafloor Biosphere*. The oceanic crust contains the largest aquifer on Earth. Thermal circulation and reactivity of seawater-derived fluids modifies the mineralogy of oceanic crust and sediments, leads to the formation of hydrothermal vents that support unique micro- and macro-biological communities, and concentrates methane to form massive methane gas and methane hydrate reservoirs. The role that transient events (e.g., earthquakes, volcanic eruptions, and slope failures) play in these fluid-rock interactions and in the dynamics of benthic and sub-seafloor microbial communities remain largely unknown.
- *Plate-Scale, Ocean Geodynamics*. Lithospheric movements and interactions at plate boundaries at or beneath the seafloor are responsible for short-term events such as earthquakes, tsunamis, and volcanic eruptions. These tectonically active regions are also host to the densest hydrothermal and biological activity in the ocean basins. The degree to which active plate boundaries influence the ocean from a physical, chemical, and biological perspective are largely unexplored.

Current Status

In FY 2016, the OOI infrastructure is operating, transmitting ocean data to storage, and incrementally delivering processed datasets and data products via the website. Refurbishment and redeployments of the moorings, instruments, and platforms are planned and being executed. Data quality management is maturing and the OOI Science Team is conducting outreach to the science community on the quality assurance/quality control (QA/QC) methods and procedures being used. The OOI Operations and Maintenance (O&M) budget for FY 2017 is $50.0 million. This funding request includes the costs for all parts, labor, equipment, ship time, and cyberinfrastructure to manage, operate, and maintain the OOI. Deployed Coastal OOI instruments are visited and replaced twice per year. The Cabled and Global instruments are replaced annually. The O&M budget also includes science, engineering, and management staff to deliver scientific data of known quality, as well as the planning and engineering execution required for safe operations of the facility.



OOI Global Surface Mooring Deployed in the Irminger Sea. *Credit: Allison Heater, Woods Hole Oceanographic Institution.*

Total Obligations for OOI

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	55.00	55.00	50.00	44.00	44.00	44.00	44.00	44.00

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only.

The Consortium for Ocean Leadership (OL) is the awardee for OOI Operations and Maintenance. OL has major sub-awardees on the project team to operate and maintain the marine infrastructure, manage the scientific data, and operate the cyberinfrastructure. The University of Washington operates the OOI Cabled Array. Oregon State University operates the Coastal Endurance Array. Woods Hole Oceanographic Institution operates the Pioneer Coastal Array as well as the Global Arrays at the four OOI Global sites. Rutgers University manages the OOI data as well as the cyberinfrastructure and Education and Public Outreach. Raytheon Corporation provides project management support, systems engineering, and software services for the OOI cyberinfrastructure.

Management and Oversight

- NSF Structure: The Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO) manages OOI operations located within the Integrative Programs section. The oversight includes the review of observatory metrics and data quality management, as well as integration of the OOI with any new science or infrastructure proposals.
- External Structure: Based on a request from NSF, the University National Oceanographic Laboratory System (UNOLS) Council established the Ocean Observatory Science Committee (OOSC). The OOSC provides guidance and science user perspectives on the operations and maintenance for OOI and several other NSF-funded ocean observatories. The OOSC will conduct science user workshops in FY 2016 and FY 2017. The OOI Program has a Science Oversight Committee which provides input and guidance to Ocean Leadership for OOI infrastructure planning and management.
- Reviews: In 2015, NSF conducted two reviews (March and May) of the construction completion. Annual operations and maintenance reviews will take place in FY 2016 and FY 2017.

Operations Costs

Operations and maintenance in support of scientific research began in FY 2013 with the deployment of the first OOI instruments. The associated costs have been and will continue to be supported by OCE, with temporary support from the Division of Integrative and Collaborative Education and Research (ICER) from FY 2015-FY 2017. Support for research utilizing observatory data will be through the standard NSF proposal submission process to existing science programs in OCE, however, because the data is freely available over the internet, researchers around the world will have access to the unique data sets OOI will produce regardless of the source of their support.

Education and Outreach

The OOI website and infrastructure provides an education portal to enable undergraduate level tools for education. The OOI Science Oversight Committee actively conducts outreach activities regarding the ocean science datasets to researchers, public and education users.

Renewal/Recompetition/Termination

The OOI O&M cooperative agreement with OL ends in FY 2017. A re-competition for the O&M for OOI will be conducted in FY 2016.

POLAR FACILITIES AND LOGISTICS

$312,070,000
+$11,000,000 / 3.7%

Polar Facilities and Logistics

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
Polar Facilities	$193.93	$194.14	$202.14	$8.00	4.1%
Polar Logistics	124.30	106.93	109.93	3.00	2.8%
Total, Polar Facilities and Logistics	**$318.23**	**$301.07**	**$312.07**	**$11.00**	**3.7%**

Totals may not add due to rounding.

New mandatory funding ($11.0 million) will support one-time investments to enhance infrastructure.

Polar Facilities

The Division of Polar Programs (PLR) within the Directorate for Geosciences (GEO) provides the infrastructure needed to support U.S. research conducted in Antarctica, including research funded by NSF and by U.S. mission agencies, for year-round work at three U.S. stations, on two research ships, and at a variety of remote field camps. Support to other agencies includes mission-essential satellite communications support at McMurdo Station for the Joint Polar Satellite System (JPSS), and the National Aeronautics and Space Administration's (NASA) Ground Networks for the relay of data. Through a partnership with the National Oceanic and Atmospheric Administration (NOAA), NASA, and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), PLR supports the relay of real-time satellite-based weather information that informs global forecasting. In addition, PLR enables important climate monitoring activities for NOAA at the Clean Air Facility at South Pole Station, one of only five such sites around the globe. PLR also provides support for: NASA's Long Duration Balloon program that enables research in fields ranging from astrophysics to cosmic radiation to solar astronomy; the South Pole Remote Earth Science and Seismological Observatory (SPRESSO), the most seismically-quiet station on earth and a key site contributing to U.S. activities associated with the Comprehensive Test Ban Treaty and to U.S. Geological Survey (USGS) and NSF efforts for global seismic monitoring; and access to sites that are key to precise orbit determinations for optimizing use of the Global Navigation Satellite System (GNSS).

All support for these activities is provided by PLR, including transportation, facilities, communications, utilities (water and power), health and safety infrastructure, and environmental stewardship. The U.S. Antarctic Program (USAP) maintains the U.S. presence in Antarctica in accordance with U.S. policy, and supports Antarctic Treaty administration under State Department leadership.

Total Obligations for Polar Facilities

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Antarctic Infrastructure and Logistics	$193.93	$194.14	$202.14	$194.14	$194.14	$194.14	$194.14	$194.14
Total, Polar Facilities	**$193.93**	**$194.14**	**$202.14**	**$194.14**	**$194.14**	**$194.14**	**$194.14**	**$194.14**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only.

PLR contracts with a prime contractor for science support, operations, the leasing of research vessels, and the maintenance of the Antarctic stations and related infrastructure in New Zealand and Chile. The contractor is selected through a competitive process. Rotary- and fixed-wing aircraft used in support of research are also provided through separate competitively-awarded contracts. Other agencies and contractors provide technical support in areas of expertise such as engineering, construction, and communications. Following a major refurbishment program, the U.S. Coast Guard's (USCG) *Polar Star* has returned to service and is expected to provide icebreaking services for the McMurdo Station resupply effort through the end of her extended service life (in approximately 2022).

Management and Oversight

Helicopters provide support to field parties in the McMurdo Dry Valleys in southern Victoria Land and at remote field camps. *Credit: Kristan Hutchison, RPSC*

- NSF Structure: PLR staff, including subject matter experts in operational and scientific disciplines, have overall responsibility for funding and managing Polar Facilities under the USAP that NSF budgets for and manages on behalf of the Nation. This includes planning all activities and overseeing contractors. PLR's Antarctic Sciences section funds merit-reviewed research proposals for which access to Antarctica is essential to advancing the scientific frontiers and that can only be achieved or are best achieved with research work in Antarctica and the Southern Ocean. Research is conducted in a broad array of geo- and bio- sciences, including earth system science, as well as space and astrophysical sciences. The Antarctic Infrastructure & Logistics section enables research in Antarctica on behalf of the U.S. government through a network of stations, labs, equipment, and logistical resources. The Environment, Health, and Safety section oversees the environmental, health, and safety aspects of research and operations conducted in Polar Regions.
- External Structure: The Antarctic support contract was competed and awarded to Lockheed Martin Corporation in December 2011. There are many separate subcontractors for supplies and technical services, and other services are procured through separate competitively-bid contracts.
- Reviews: PLR evaluates the performance of the Antarctic support contractor annually via an Award Fee Plan, which involves multiple tiers of review, including a Performance Evaluation Board (PEB) composed of representatives from PLR and the Office of Budget, Finance, and Award Management (BFA). In addition, PLR's performance is reviewed externally by Committees of Visitors and the GEO Advisory Committee. The USAP Blue Ribbon Panel (BRP) released a report on its review of the program in July 2012.[19] The NSF response to the USAP BRP report was released in March 2013.[20]

Current Status

- All facilities (stations, research vessels, and field camps) are currently operating normally.
- The USAP BRP report concluded that ushering in a new age of Antarctic science simply by expanding traditional methods of logistical support would be prohibitively costly. Instead, it recommended numerous ways to more efficiently and cost-effectively support research while maintaining high standards of safety and increasing the flexibility to support evolving science foci in the future. Continued progress is planned to implement BRP recommendations, including investment in prioritized lifecycle acquisitions. Priority will also be given to site work that would be needed to support implementation of the Antarctic Infrastructure Modernization for Science (AIMS) project, currently in the early stages of design. While overall project scope is still being refined, the AIMS project is preparing plans for redevelopment of McMurdo Station to be a smaller, more efficient facility. Also in

[19] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp
[20] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/nsf_brp_response.pdf

planning stages are replacing major logistic facilities concerning the airplane runway and vessel operations; upgrading facilities for fuel containment, utilities distribution, and fire protection; upgrading satellite communications systems to support operations and research; and possible replacement of the Palmer Station pier to ensure long-term access to unique research in the peninsula region. Additional information is included in the PLR narrative in the GEO chapter.

Renewal/Recompetition/Termination

- In FY 2012, Lockheed Martin Corporation was awarded a 13.5-year contract, consisting of a five-year base period and four option periods, exercised on the basis of performance, that total an additional 8.5 years.
- Contracts for fixed and rotary wing support are managed as assisted acquisitions by the Department of Interior, Office of Aviation Services. A five-year contract for helicopter support was awarded to PHI, Inc. of Lafayette, Louisiana, in May 2013. The current five-year contract for fixed-wing aviation services, currently held by Kenn Borek Air of Calgary, Canada, is up for renewal and will be re-competed in the spring of 2016.
- U.S. policy directs NSF to maintain an active and influential presence in Antarctica, including year-round occupation of South Pole Station and two coastal stations. As the scientific forefronts addressed there evolve over time, so do the research emphases at the three stations and the infrastructure needed to support them.

Polar Logistics

Polar Logistics consists of two activities: the U.S. Antarctic Logistical Support program within the Antarctic Infrastructure and Logistics section, and the Research Support and Logistics program within the Arctic Sciences section.

Total Obligations for Polar Logistics

(Dollars in Millions)

				ESTIMATES[1]				
	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
U.S. Antarctic Logistical Support	$67.52	$67.52	$67.52	$67.52	$67.52	$67.52	$67.52	$67.52
Arctic Research Support and Logistics	56.78	39.41	42.41	39.41	39.41	39.41	39.41	39.41
Total, Polar Logistics	**$124.30**	**$106.93**	**$109.93**	**$106.93**	**$106.93**	**$106.93**	**$106.93**	**$106.93**

Totals may not add due to rounding.

The U.S. Antarctic Logistical Support program funds support activities provided by the U.S. Department of Defense (DoD). DoD operates as a logistical support provider on a cost-reimbursable basis. Major funding elements of DoD support include: military personnel, LC-130 flight operations, and maintenance support through the 109th Airlift Wing of the New York Air National Guard in Scotia, New York, and Antarctica; transportation and training of military personnel supporting the USAP; support for air traffic control, weather forecasting, and ground electronics maintenance; the charter of Air Mobility Command airlift and Military Sealift Command ships for the re-supply of McMurdo Station; bulk fuel purchased from the Defense Logistics Agency; and reimbursement for use of DoD satellites for communications.

The Research Support and Logistics program in the Arctic Sciences section of PLR responds to science supported by the section. Funding is provided directly to grantees or to key organizations that provide or manage Arctic research support and logistics. A contractor provides research support and logistics services for NSF-sponsored activities in the Arctic. Additional major support components include: access to USCG and other icebreakers, University-National Oceanographic Laboratory (UNOLS) vessels and coastal boats;

access to fixed- and rotary-wing airlift support; upgrades at Toolik Field Station, University of Alaska Fairbanks' field station for ecological research on Alaska's North Slope; safety training for field researchers and funding for field safety experts; global satellite telephones for emergency response and improved logistics coordination; and development of a network of strategically placed U.S. observatories linked to similar efforts in Europe and Canada.

Management and Oversight

- NSF Structure: PLR has overall responsibility for U.S. Antarctic Logistical Support and Arctic Research Support & Logistics.
  - U.S. Antarctic Logistical Support is budgeted for and managed by the Antarctic Infrastructure and Logistics Section, which includes managers with operational expertise responsible for planning and overseeing all USAP support.
  - Arctic Sciences personnel support merit-reviewed research proposals in social, earth systems, and a broad range of natural sciences; its Research Support & Logistics program responds to research by assisting researchers with access to the Arctic and sharing of plans and results with local Arctic communities.
  - The Environment, Health, and Safety section oversees the environmental, health, and safety aspects of research and operations conducted in polar regions.
- External Structure:
  - DoD operates as a logistical support provider on a cost-reimbursable basis. The agencies cooperate under a Memorandum of Agreement that includes guidance for planning and scheduling and sets forth the terms and conditions for reimbursement to DoD by NSF.
  - The Arctic support contract was re-competed and awarded to the incumbent, CH2M Hill, in September 2011. There are many separate subcontractors for supplies and technical services, and other services are procured through separate competitively bid contracts.
- Reviews: PLR evaluates the performance of the Arctic support contractor informally on an ongoing basis and formally each year using feedback from the research community they support, and by conducting site visits that include representatives from PLR and BFA. PLR's performance is externally reviewed by Committees of Visitors and the GEO Advisory Committee.

Current Status

All facilities (stations, research vessels, and field camps) are currently operating as normal.

Renewal/Recompetition/Termination

NSF recompeted the Arctic support contract and made an award to the incumbent contractor, CH2M Hill, in September 2011. The contract has an initial term of four years and the possibility of two, two-year extensions exercised on the basis of performance.

SEISMOLOGICAL FACILITIES FOR THE ADVANCEMENT OF GEOSCIENCE AND EARTHSCOPE — $26,950,000 +$2,600,000 / 10.7%

Seismological Facilities for the Advancement of Geoscience and EarthScope

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$24.35	$24.35	$26.95	$2.60	10.7%

New mandatory funding ($2.60 million) will support one-time investments to enhance infrastructure at this facility.

The Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE) comprise a distributed, multi-user, national facility for the development, deployment, and operational support of modern digital seismic instrumentation to serve national goals in basic research and education in the earth sciences, earthquake research, global real-time earthquake monitoring, and nuclear test ban verification. SAGE is managed and operated for NSF by the Incorporated Research Institutions for Seismology (IRIS), a consortium of 122 U.S. universities and non-profit institutions with research and teaching programs in seismology, 21 educational affiliates, three U.S. affiliates, and 128 foreign affiliates. SAGE was formed in late FY 2013 from part of the EarthScope program and the IRIS facility. The FY 2017 Request will allow SAGE to continue providing service to the community consistent with that in previous years.

Total Obligations for SAGE

(Dollars in Millions)

	FY 2015	FY 2016	FY 2017	ESTIMATES[1]				
	Actual	Estimate	Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	$24.35	$24.35	$26.95	$24.35	$24.35	$24.35	$24.35	$24.35

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2018.

The Earth's interior remains a major scientific frontier holding the key to understanding the origin of the planet. Recent developments in seismic sensor design, and the acquisition, transmission, and storage of data have resulted in dramatic improvements in the resolving power of seismic imaging of the interior. To serve the research needs of the broad earth science community, SAGE is organized under three primary service areas and two special emphasis areas:

Instrumentation Services

- The Global Seismographic Network (GSN) consists of over 150 permanently-installed broadband digital seismic stations, most of which have real-time data access. GSN is operated in partnership with the U.S. Geological Survey (USGS).
- Portable Seismology (PS) includes a pool of over 5,200 portable seismometers that are made available to the earth science research community for a wide range of principal investigator-driven experiments largely funded through the NSF merit review process.
- Polar Support Services (PSS) supports the development of specialized seismic equipment for use in harsh environments and provides instrumentation, training, and field support for experiments in the polar regions. Additional supplemental funding for these activities is provided through the Division of Polar Programs (PLR).
- The Transportable Array (TA) is a continental-scale seismic observatory designed to provide a

foundation for multi-scale integrated studies of continental lithosphere and deep Earth structure. Over 1,700 TA stations operated across the lower 48 states and southern Ontario and Quebec, Canada, between 2004 and 2015; TA is now being deployed to Alaska and western Canada.

- The Magnetotelluric (MT) component exploits the natural variations in Earth's magnetic and electric fields to provide information on the distribution and composition of fluids in Earth's crust and upper mantle, which gives constraints on Earth's structure that are complementary to those resulting from seismology.
- Instrumentation Services-Coordinated Activities include efforts to develop the next generation of seismic instrumentation for large-scale scientific experiments; global-scale geophysical networks; and training courses to distribute best practices to partners worldwide.

Data Services

- SAGE Data Services (DS) manages an archive of over 350 terabytes of seismic, magnetotelluric, and other data from all SAGE components, the EarthScope program, and numerous affiliated networks; operates automated and manual systems to ensure the quality of all data stored in the archive; and provides systems to give the national and international research community timely access to these data. In the last quarter of FY 2015, nearly 20,000 unique users downloaded over 100 TB of data from the SAGE archive.

Education and Public Outreach

- The SAGE Education and Public Outreach (EPO) program enables audiences beyond seismologists to access and use seismological data and research, including student internships, and programs for under-resourced educational institutions.

Special Emphasis Areas

- Community Activities include scientific and technical workshops that bring together the international seismic community and publications designed to communicate SAGE activities and results to the community.
- International Development Seismology (IDS) leverages the core SAGE service areas to provide capacity building and training for earthquake hazard mitigation in developing countries, through technical assistance and research collaborations with scientists at U.S. academic institutions.

Besides its role in providing the observational data essential for basic earth science research, SAGE also provides real-time seismic data to the USGS and the National Oceanic and Atmospheric Administration (NOAA) for global earthquake, volcano, and tsunami monitoring; international seismic monitoring of compliance with the Comprehensive Test Ban Treaty; and bringing seismology to students and the public through the activities of its EPO program.

SAGE is heavily involved in partnership activities, many international in nature. Installation and operation of the GSN has put IRIS in contact with scientists, as well as government and non-governmental organizations, from around the world. Many international GSN stations are designated as the official stations for nuclear test ban monitoring in their host countries. SAGE also provides multi-use resources for other government agencies that have responsibilities for development of a nuclear test ban monitoring capability and for monitoring global seismicity. For these purposes, agencies in partnership with NSF have provided substantial support for accelerated development of the GSN, shared operation and maintenance of the GSN, and accelerated development of the PS instrument pool.

The EarthScope, Geophysics, GeoPRISMS, and Tectonics Programs in the Division of Earth Sciences (EAR); the GeoPRISMS and Marine Geology and Geophysics Programs in the Division of Ocean Sciences (OCE); and the Geology and Geophysics Program and the Glaciology Program in the Antarctic Research

Section of PLR provide most of the funds, totaling approximately $15.0 million per year, for NSF-sponsored research making use of SAGE. Funds permit deployment of portable seismic instruments and use of data managed by DS to solve major Earth science problems.

Management and Oversight

- NSF Structure: EAR, through its Instrumentation & Facilities program (IF), provides general oversight of SAGE to help assure effective performance and administration. The program also facilitates coordination of SAGE programs and projects with other NSF-supported facilities, and with other federal agencies, and evaluates and reviews the performance of IRIS in managing and operating SAGE.
- External Structure: SAGE is managed and operated by IRIS, which is incorporated as a non-profit consortium representing 122 U.S. universities and non-profit organizations with research and teaching programs in seismology. Each voting member institution of the Consortium appoints a member representative, and these member representatives elect the nine members of the IRIS Board of Directors. The Board members, who serve three-year terms, vet all internal program decisions associated with SAGE management and operation, through consultation with IRIS staff and SAGE advisory committees (one for each major SAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of IRIS to a renewable two-year term. The president is responsible for IRIS operations, all of which are managed through the IRIS Corporate Office located in Washington, DC.
- Reviews: All major ongoing geoscience facilities routinely undergo mid-award reviews of their management, in addition to peer review of proposals for new or continued support. The formal NSF merit review of the five-year proposal for the SAGE facility took place in 2012 and 2013 and was also the most recent review of IRIS. Although the *ad hoc* reviewers and two independent review panels had a number of specific recommendations at the working level for SAGE, overall the review found that SAGE was a critical facility for U.S. and international earth sciences. Furthermore, the reviewers found that IRIS is a well-managed and effective organization that has, through its commitment to the collection and open dissemination of the highest quality seismological data, transformed the discipline of seismology. In FY 2015, the GSN underwent external review by an international committee, which concluded in part that "…continued federal funding of the GSN and broad community participation are essential to the future of basic and applied seismological research and the use of this research in support of agency missions."

Renewal/Recompetition/Termination

Funding for the current cooperative agreement for SAGE began in FY 2014 and ends in FY 2018. In FY 2016, in keeping with the phased integration and recompetition plan presented to and concurred with by the National Science Board in December 2009, NSF intends to solicit proposals for a future facility or facilities to support the earth sciences research and education community currently supported by SAGE and the related Geodesy Advancing Geoscience and EarthScope (GAGE). NSF is currently considering the precise form of this solicitation, and any possible future facility/facilities are currently being considered within NSF and through discussions with the SAGE and GAGE support communities.

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCs)

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH $101,000,000 +$1,300,000 / 1.3%

National Center for Atmospheric Research
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$98.70	$99.70	$101.00	$1.30	1.3%

New mandatory funding ($1.30 million) will support one-time investments to enhance infrastructure at this facility.

The National Center for Atmospheric Research (NCAR) is a Federally-Funded Research and Development Center (FFRDC) serving a broad research community, including atmospheric and geospace scientists and researchers in complementary areas of the environmental sciences and geosciences. NCAR is managed under a cooperative agreement between NSF and the University Corporation for Atmospheric Research (UCAR), a university-governed and university-serving organization comprising 105 degree-granting academic institutions.

As of December 2015, NCAR supported a total of 751.1 full time equivalents (FTEs), of which 326.8 are funded under the NSF primary award to UCAR.

Number of FTEs Supported at NCAR

FTEs	Primary Award[1]	All Funding
Career Scientists	75.3	107.7
Scientific Support[2]	222.3	511.2
Other Staff[3]	29.2	132.2
Total	**326.8**	**751.1**

[1] The primary award also includes funding for non-staff costs, such as infrastructure.
[2] Scientific Support includes associate scientists, project scientists, post docs, software engineers, engineers, system support and technicians.
[3] Other Staff includes administrative positions, managers, paid visitors, pilots, and mechanics.

NCAR provides facilities, including world-class supercomputing services, research aircraft, a transportable ground-based radar system, atmospheric sounding, and other surface sensing systems to university, NCAR, and other atmospheric researchers. NCAR operates several facilities dedicated to the study of the Sun and solar phenomena (e.g., the Mauna Loa Solar Observatory), space weather, and the responses of the upper atmosphere to the Sun's output.

Total Obligations for NCAR

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Aircraft Support	$9.31	$9.40	$9.52	$9.40	$9.40	$9.40	$9.40	$9.40
Computational Infrastructure	28.21	28.50	28.87	28.50	28.50	28.50	28.50	28.50
Other Facility Support	20.22	20.42	20.69	20.42	20.42	20.42	20.42	20.42
Research & Education Support	40.96	41.38	41.92	41.38	41.38	41.38	41.38	41.38
Total, NCAR	**$98.70**	**$99.70**	**$101.00**	**$99.70**	**$99.70**	**$99.70**	**$99.70**	**$99.70**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only.

Partnerships and Other Funding Sources: NCAR leverages NSF support with funding provided by other federal agencies and non-federal sources. In FY 2015, NCAR received approximately $38.88 million in support from other federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy (DOE), and the Federal Aviation Administration (FAA), and $17.74 million from non-federal sources.

Major Investments in FY 2017: In FY 2017, investments at NCAR will focus on fundamental research aimed at improving our ability to predict atmospheric, chemical, and space weather hazards, and increasing our understanding of the variability in the Earth's climate system at regional and global scales. In all of these areas, NCAR scientists will work with their university colleagues to further understand the fundamental processes that control the Earth's climate and weather systems. This will include research thrusts in areas such as the role of the chemical composition of the atmosphere and impacts of changes in that composition on the climate system, better understanding of the structure and nature of hurricanes and other severe weather events, and the impacts of the Sun on space weather and weather on Earth.

Aircraft Support: NCAR operates two NSF aircraft: a C-130Q Hercules and a Gulfstream-V (G-V, also known as the High-Performance Instrumented Airborne Platform for Experimental Research, or HIAPER), both of which are highly modified and equipped with specialized instrumentation, to enable the support of research activities designed to provide new insights into atmospheric chemical processes, the dynamics and coupling of the atmosphere's layers, and interactions between the atmosphere and Earth's surface. The two aircraft will support several community-originated projects deemed by peer review to be of exceptional scientific merit.

Computational Infrastructure: NCAR operates a petascale supercomputing facility in Cheyenne, Wyoming (the NCAR-Wyoming Supercomputing Center), that supports high-end community modeling programs in climate, weather, and other Earth Systems processes. These include the Community Earth System Model (CESM) and the Weather Research and Forecasting Models (WRF), which use mathematical formulas to simulate and better understand the chemical and physical processes that drive Earth's climate and weather system. NCAR leads the development of these community models and supports many thousands of users in the U.S. and worldwide. NCAR also maintains extensive data archives, providing access to a vast collection of observational, experimental, and modeling data, together with sophisticated analysis and visualization facilities, and training and support for users of all levels.

Other Facility Support: In addition to the C-130 and G-V aircraft, NCAR provides support for a number of other atmospheric observing platforms through its Earth Observing Laboratory (EOL), including a large, deployable, dual-wavelength Doppler radar, upper atmosphere observing capabilities, an advanced coronagraph, and other experimental systems.

Research and Education Support: Total funding for research and education support at NCAR is estimated to be $41.92 million in FY 2017. As an internationally recognized center of excellence, NCAR operates scientific research programs that include the following areas:

- studies of large-scale atmospheric and ocean dynamics that contribute to an understanding of the past and present climate processes and global climate change;
- global and regional atmospheric chemistry, including atmospheric connections to geochemical and biogeochemical cycles;
- the variable nature of the sun and the physics of the corona and their interaction with the Earth's magnetic field;
- the physics of clouds, thunderstorms, precipitation formation, and their interactions and effects on local and regional weather; and
- examination of human society's impact on atmospheric composition, weather, and climate, and response to global environmental change.

Research collaborations among NCAR staff and university colleagues are integral to its success as an institution, and serve as a focus and meeting point for the broader atmospheric and related sciences community. NCAR also maintains extensive partnerships and collaborations with the private sector through directed research and technology transfer. This work focuses on developing weather and climate information tailored to the specific needs of stakeholders in a variety of sectors, including energy, aviation, and agriculture.

The Mesa Laboratory, designed by architect I.M. Pei, in Boulder, CO. *Credit: NCAR.*

Educational activities include the SOARS (Significant Opportunities in Atmospheric Research and Science) program that integrates research, education, and mentoring to bridge the undergraduate-to-graduate transition and to broaden participation in the atmospheric and related sciences.

In addition, NCAR further supports the scientific community by providing fellowships, internships, workshops, and colloquia for students and visiting scientists, and disseminates knowledge of the geosciences. Professional training courses, innovative and award-winning science education websites,[21] as well as the directed activities of NCAR's education and outreach programs are further examples of how NSF's goal of integrating research and education is attained through NCAR activities.

Management and Oversight

- NSF Structure: NSF's Division of Atmospheric and Geospace Sciences (AGS), along with the Division of Acquisition and Cooperative Support (DACS), provide oversight of NCAR and the cooperative agreement with UCAR for NCAR's management. The cooperative agreement encourages interactions between NCAR scientists and AGS staff and ensures close coordination between AGS and NCAR management. The agreement contains requirements for AGS's oversight of the NCAR program and UCAR management activities that affect NCAR. These include a provision that UCAR submit for AGS approval an annual program plan that details how resources will be used. In addition, NCAR summarizes its past year's accomplishments in an annual scientific report. Annual strategic planning between AGS, UCAR, and NCAR ensure that scientific and facility priorities remain consistent with those of NSF.
- External Structure: UCAR works in partnership with NSF and the university community to ensure effective implementation of the NCAR strategic mission to the benefit of the atmospheric and geospace

[21] www.spark.ucar.edu

research community. In addition, other research sponsors, such as NOAA, the National Aeronautics and Space Administration (NASA), DOE, the Department of Defense (DOD), the Environmental Protection Agency (EPA), and the FAA support research collaboration wherever it enhances NCAR's NSF-supported research goals or facilities missions.

- Reviews: A Committee of Visitors (COVs) is convened periodically to evaluate AGS oversight of NCAR. The most recent COV was conducted in FY 2015 with the next anticipated in FY 2019. A Business Systems Review was conducted in FY 2011, and the next review will take place in FY 2016. No significant issues were raised in either of the most recent reviews.

Renewal/Recompetition/Termination

Based on a thorough review of NCAR's performance as a center and UCAR's management of NCAR undertaken in 2011, UCAR was awarded a new cooperative agreement to manage NCAR for the five-year period FY 2014-2018. It is anticipated that the cooperative agreement for management of NCAR will be recompeted prior to the next award period, beginning in FY 2019.

NATIONAL OPTICAL ASTRONOMY OBSERVATORY **$21,830,000**
+$230,000 / 1.1%

National Optical Astronomy Observatory

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Percent
$25.50	$21.60	$21.83	$0.23	1.1%

The National Optical Astronomy Observatory (NOAO) was established in 1982 by uniting operations of the Kitt Peak National Observatory (KPNO) in Arizona and the Cerro Tololo Inter-American Observatory (CTIO) in Chile. As a Federally Funded Research and Development Center sponsored by NSF, the primary purpose of NOAO is to serve as the U.S. national center for ground-based optical and infrared (OIR) astronomy to coordinate/integrate/operate observational, technical, and data-oriented capabilities available throughout the U.S. OIR system of federal and non-federal assets.

NOAO's mission is to enable discovery in ground-based OIR astronomy. In pursuit of this mission, NOAO facilitates access for all qualified professional researchers to state-of-the-art observational capabilities and databases in OIR astronomy. NOAO enables the U.S. research community to pursue a broad range of modern astrophysical challenges from small bodies within the Solar System, to the most distant galaxies in the early Universe, to indirect observations of dark energy and dark matter. NOAO is the gateway for the U.S. astronomical community to the Gemini Observatory through the U.S. National Gemini Office (US-NGO). NOAO coordinates community access to telescopes throughout the U.S. OIR system, and it facilitates connecting the scientific user to data archives by developing and maintaining data management capabilities. NOAO integrates community planning for future facilities and instrumentation projects under a national organization. In partnership with the community and NSF, NOAO works with colleges and universities to train the next generation of scientists and engineers, and promotes accomplishments to strengthen education and public awareness of the astronomical sciences.

NOAO facilities, telescopes, and data systems, are open to all qualified astronomers regardless of institutional affiliation. They serve nearly 1,200 U.S. and foreign scientists annually. Doctoral dissertation students and non-thesis graduate students from U.S. institutions use NOAO facilities for research projects. In FY 2015 NOAO employed 300 personnel in Arizona and Chile, including 45 support scientists and 10 postdoctoral fellows.

The Division of Astronomical Sciences in the Directorate for Mathematical and Physical Sciences (MPS/AST) conducted a community-based review of its portfolio in 2011-2012. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*[22] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

The recommendations from the PRC report included divesting NSF support from three nighttime OIR telescopes located on Kitt Peak: The 4-meter Mayall telescope, the 2.1-meter telescope, and the 3.5-meter WIYN telescope, which is owned and operated by a consortium of University of Wisconsin, Indiana University, and NOAO. NOAO's share of the WIYN telescope time for public access is 40 percent.

[22] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

As of October 1, 2015, the PRC recommendations have been implemented. The 2.1-meter telescope has a new operator, the California Institute of Technology, for a research program on cosmic transient phenomena. Starting in FY 2016, the NOAO base operations and maintenance budget excludes NSF funding for the Mayall and WIYN telescopes. Any subsequent NSF support for these telescopes will be as special projects with supplemental funding to NOAO.

Total Obligations for NOAO

(Dollars in Millions)

	FY 2015	FY 2016	FY 2017	**ESTIMATES**[1]				
	Actual	Estimate	Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
NOAO Base O&M	$20.00	$17.50	$18.03	$18.57	$19.12	$19.70	$20.29	$20.90
Tucson Operations	*10.50*	*8.50*	*8.76*	*9.02*	*9.29*	*9.57*	*9.85*	*10.15*
Chilean Operations	*8.00*	*8.00*	*8.24*	*8.49*	*8.74*	*9.00*	*9.27*	*9.55*
Kitt Peak Operations	*1.50*	*1.00*	*1.03*	*1.06*	*1.09*	*1.13*	*1.16*	*1.19*
Special Projects: WIYN and Mayall	5.50	4.10	3.80	2.10	1.00	1.00	1.00	1.00
Total, NOAO	**$25.50**	**$21.60**	**$21.83**	**$20.67**	**$20.12**	**$20.70**	**$21.29**	**$21.90**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2020.

Partnerships and Other Funding Sources: The managing organization for NOAO is the Association of Universities for Research in Astronomy, Inc. (AURA), which is comprised of 39 U.S. member institutions and seven international affiliate members. A key NOAO partnership is ongoing with the Department of Energy (DOE) to conduct a survey of the southern sky to investigate the nature of dark energy. The five-year Dark Energy Survey began operation in August 2013 on the CTIO 4-meter Blanco telescope. NOAO is a partner in the 4.1-meter SOAR (Southern Astrophysical Research) telescope at CTIO. SOAR partners include the University of North Carolina, Chapel Hill; Michigan State University; and the Ministério da Ciência, Tecnologia, e Inoviçao of Brasil.

A large number of U.S. universities support their own astronomical facilities at KPNO and CTIO with reimbursed services provided by NOAO. Development of new telescopes, instrumentation, and sensor techniques is done in partnership with universities and with industry through subawards to aerospace, optical fabrication, and information technology companies. NOAO leverages NSF support with funding from other federal agencies and non-federal sources. NOAO typically receives approximately $10.0 million each year for reimbursed services from partnerships and tenant observatory support, from the Kitt Peak Visitors Center, and from grants from other federal agencies.

Education and Public Outreach: NOAO supports U.S. education goals by promoting public understanding and support of science and by providing education and training at all levels. Over 200 U.S. and foreign graduate students observe on NOAO telescopes yearly and a significant fraction of the observations contribute to Ph.D. dissertations. The observatories introduce undergraduate students to scientific research by providing stimulating environments for basic astronomical research and related technologies through NSF's Research Experiences for Undergraduate Students (REU) program. NOAO has a diverse education program, visitors centers, and a web-based information portal at www.noao.edu.

NOAO Base O&M: $18.03 million, $530,000 above the FY 2016 Estimate.

Tucson Operations: $8.76 million, $260,000 above the FY 2016 Estimate: Tucson operations covers the headquarters, offices, laboratories, and workshops in Tucson, Arizona.

Chilean Operations: $8.24 million, $240,000 above the FY 2016 Estimate: This supports administration and labs in La Serena, Chile and mountain operations on Cerro Tololo and Cerro Pachón.

Kitt Peak Operations: $1.03 million, $30,000 above FY 2016 Estimate: This provides support for basic infrastructure on the mountain for the benefit of the tenants. All facilities on the mountain are accounted as tenants.

Special Projects (WIYN and Mayall): $3.80 million, $300,000 below the FY 2016 Estimate.

WIYN telescope: $1.0 million, no change from the FY 2016 Estimate: The National Aeronautics and Space Administration (NASA) has identified the WIYN telescope as the preferred platform for an extreme precision Doppler spectrometer as a facility instrument for exoplanet follow up research. This instrument is the key component of a NASA-NSF partnership in Exoplanet Observational Research (NN-EXPLORE), which began in FY 2015 using existing instrumentation on WIYN. A Memorandum of Agreement between the agencies for NN-EXPLORE was signed in FY 2015, and a Joint Oversight Group was formed early in FY 2016.

Mayall Telescope: $2.80 million, $300,000 below the FY 2016 Estimate: The decrease from FY 2016 is balanced by an equivalent increase in DOE support for the telescope. DOE identified the Mayall telescope as the preferred platform for the Dark Energy Spectroscopic Instrument (DESI) to carry out a dark energy science survey sponsored by DOE. For FY 2016 through FY 2018, the Mayall telescope will be in transition in preparation for DESI installation. During the transition period, funding from NSF will decrease while support from DOE will increase to the point where DOE is expected to assume full operations costs starting in FY 2019.

Management and Oversight

- NSF Structure: An NSF program officer in AST provides continuing oversight, including consultation with an NSF program review panel of external reviewers that meets once a year. The program officer reviews detailed annual program plans, annual long range plans, quarterly technical and financial reports, and annual reports submitted by NOAO. The NSF program officer also attends AURA governance committee meetings. Governance committees are formed from the national astronomical community and provide additional avenues for input of community priorities and concerns. The AST program officer works closely with other offices at NSF, particularly the Office of General Counsel, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- External Structure: AURA is the managing organization for NOAO. The NOAO director reports to the president of AURA, who is the principal investigator on the NSF cooperative agreement that began in FY 2016. AURA receives management advice from an observatory council composed of members of its scientific and management communities. NOAO uses a Users Committee, comprised of community scientists, to advise the NOAO director on all aspects of user experiences at the Observatory.
- Reviews: In addition to reviews held mid-way through all cooperative agreements, NSF conducts both periodic and ad hoc external reviews of AURA management. A comprehensive review of the managing organization's performance will be carried out in the fourth year of the five-year cooperative agreement.

Renewal/Recompetition/Termination

In FY 2013 NSF began the process of competing the award for the management and operation of NOAO. The competition was completed with the issuance of a new cooperative agreement with AURA starting October 1, 2015 and ending in FY 2020.

NATIONAL RADIO ASTRONOMY OBSERVATORY **\$75,250,000**
-\$6,830,000 / -8.3%

National Radio Astronomy Observatory
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request[1]	Change over FY 2016 Estimate Amount	Percent
\$83.31	\$82.08	\$75.25	-\$6.83	-8.3%

[1] The funding decrease in FY 2017 is due to the separation of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the new NRAO cooperative agreement, expected to begin in early FY 2017. The FY 2017 Request for GBO and VLBA is presented in the Other Astronomical Facilities narrative.

The National Radio Astronomy Observatory (NRAO) conceives, designs, builds, operates, and maintains state-of-the-art radio telescopes used by scientists from around the world. Operating synergistically with optical, infrared, and x-ray telescopes, NRAO facilities enable discovery over a remarkably broad range of key problems in modern astrophysics that reach from within our solar system to the most distant galaxies in the universe. Using NRAO observing capabilities and data archives, scientists: carry out precision cosmological measurements; test fundamental physics; probe deep into the earliest, most intense, and optically obscured phases of planet, star, galaxy, and black hole formation; reveal the cool gas from which stars form; provide essential tools for studying magnetic fields and high-energy cosmic phenomena; and seek to detect gravitational waves.

As a Federally Funded Research and Development Center, headquartered in Charlottesville, Virginia, NRAO operates the Karl G. Jansky Very Large Array (VLA) near Socorro, New Mexico and is also the North American implementing organization for the international Atacama Large Millimeter/submillimeter Array (ALMA). These ground-based observing facilities for radio astronomy are available to any qualified researcher, regardless of affiliation or nationality, on the basis of scientific, merit-reviewed proposals. NRAO facilities annually serve over 2,500 users worldwide; moreover, growing demand for ALMA has resulted in the most proposals ever received for an astronomical facility in response to a single proposal call. NSF does not provide individual investigator awards targeted specifically for use of NRAO facilities, but many users are supported through NSF or NASA grants to pursue scientific programs that require use of NRAO facilities.

In 2010, the National Research Council conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics,*[23] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences (AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges,*[24] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

The PRC Committee report gave very high priority ranking to two NRAO telescopes: ALMA and the VLA. Two other telescopes, the Robert C. Byrd Green Bank Telescope (GBT) and the Very Long Baseline

[23] www.nap.edu/catalog.php?record_id=12951
[24] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Array (VLBA), were recommended for divestment from AST funding because of less compelling mapping onto the science questions of the 2010 decadal survey. In FY 2012 and FY 2013, AST began to engage actively in facility partnership discussions for GBT and VLBA with other federal agencies and with university-based groups. The Green Bank Observatory (GBO) (comprising GBT and the Green Bank site and facilities) and VLBA were partitioned from the NRAO management competition to facilitate other unconstrained partnership discussions separate from the open management competition. In FY 2014 and FY 2015, AST continued these other partnership discussions, and NSF brought a general engineering contractor on-board for all its engineering and environmental reviews. In FY 2016, that contractor is producing feasibility reports for divestment alternatives, which will provide the results of baseline structural and environmental surveys of the GBO and VLBA. Should viable options be identified and the decision made to divest, NSF will embark on formal reviews (in FY 2016 and FY 2017) to evaluate environmental impacts of these alternatives, including potential impacts of partnership opportunities.

Including the ALMA operations staff located at NRAO, staff in FY 2017 will consist of 337 full-time equivalent positions (FTEs) in the operations and maintenance components: 153 in telescope operations, 26 in science support and research, 43 in development programs, 62 in computing and data management, 32 in administrative services, and 22 in the director's office. These numbers exclude staff at the partitioned GBT and VLBA telescopes which will be managed and operated separately from NRAO. In addition, the NRAO managing organization, Associated Universities, Inc. (AUI), employs local ALMA operations staff in Chile, currently consisting of approximately 220 FTEs.

Total Obligations for NRAO

(Dollars in Millions)

	FY 2015	FY 2016	FY 2017	**ESTIMATES**[1]				
	Actual	Estimate	Request	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance[2]	$43.14	$41.73	$32.00	$32.96	$33.95	$34.97	$36.02	$37.10
Telescope Operations	*17.63*	*17.07*	*12.53*	*12.91*	*13.29*	*13.69*	*14.10*	*14.53*
Development	*2.73*	*2.60*	*1.73*	*1.78*	*1.84*	*1.89*	*1.95*	*2.01*
Science Operations	*5.37*	*5.16*	*5.27*	*5.43*	*5.59*	*5.76*	*5.93*	*6.11*
Administrative Services	*13.99*	*13.59*	*9.92*	*10.21*	*10.52*	*10.84*	*11.17*	*11.49*
Directors Office	*3.42*	*3.31*	*2.55*	*2.63*	*2.71*	*2.79*	*2.87*	*2.96*
ALMA Operations	40.17	40.35	43.25	44.55	45.88	47.26	48.68	50.14
Total, NRAO	**$83.31**	**$82.08**	**$75.25**	**$77.51**	**$79.83**	**$82.23**	**$84.70**	**$87.24**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2016.

[2] The funding decrease, starting in FY 2017, is due to the separation of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the new NRAO cooperative agreement, expected to begin in early FY 2017. The FY 2017 Request for GBO and VLBA is presented in the Other Astronomical Facilities narrative.

The FY 2017 Request for NRAO is below the FY 2016 Estimate due to the partitioning of GBO and VLBA. GBO and VLBA are presented in the "Other Astronomical Facilities" narrative in the Facilities chapter of this document.

Partnerships and Other Funding Sources: NRAO supplements AST support with funding provided by other NSF sources, other federal agencies, and non-federal sources. In FY 2015, NRAO received approximately $280,000 from non-AST sources at NSF, $1.42 million from other federal agencies, and $3.33 million from U.S. universities, foreign scientific and technical institutes, and other non-federal and industrial sources. The development of new telescopes, instrumentation, and sensor techniques is conducted in partnership with relevant industries through competitive sub-awards to various large and small aerospace companies, radio antenna manufacturing firms, and specialized electronics and computer hardware and software companies.

Education and Public Outreach: NRAO supports a comprehensive outreach program that makes information about radio astronomy available to the public.[25] With over 150 students involved per year, NRAO facilities are used by graduate students carrying out dissertation research and work experience programs and by undergraduate students participating in the Research Experiences for Undergraduates (REU) program. NRAO also supports a visitor and education center and conducts active educational and public outreach programs. The VLA visitor center attracts over 20,000 public visitors each year.

Telescope operations, $12.53 million: This encompasses support for direct telescope and array operations of the VLA including maintenance, infrastructure upgrades, and telescope management.

Development, $1.73 million: Development programs include next generation electronics and detectors for radio astronomy, making fundamental contributions to materials science, the physics of quantum detectors, electromagnetics, photonics, and radio propagation.

Science operations, $5.27 million: This area includes telescope time allocation, staff research, science training and education, and science community outreach.

Administrative services, $9.92 million: This includes internal common costs used to allocate common and management expenses across the total pool of observatory activity, such as business services, utilities, and other facility costs at the operating locations, observatory management, and the library.

Director's office, $2.55 million: This includes support for the Director's office, news and public information, and managing organization costs.

ALMA Operations, $43.25 million: In FY 2015, NRAO completed construction of the international ALMA Observatory, funded through the Major Research Equipment and Facilities Construction (MREFC) account. Early operations funding for ALMA began in FY 2005 and ramps up to full operations on FY 2017. Operations funding supports a share of observatory operations in Chile, a technical development program, and the North American ALMA Science Center (NAASC). NRAO created the NAASC in 2006 to provide technical and scientific support for, and easy access by, the broad astronomical community that uses ALMA. The NAASC also organizes summer schools, workshops, and courses in techniques of millimeter and submillimeter astronomy.

Management and Oversight

- NSF Structure: In consultation with community representatives, a dedicated AST program officer carries out continuing oversight and assessment for NRAO and ALMA by making use of detailed annual program plans, long-range plans, quarterly technical and financial reports, and annual reports submitted to NSF. The AST program officer participates in the international ALMA Board and attends AUI/NRAO governance and advisory committee meetings. To address issues as they arise, AST works closely with other NSF offices, such as the Office of General Counsel, the Office of International Science and Engineering, the Division of Acquisition and Cooperative Support, and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- External Structure: Management is through a cooperative agreement with AUI. AUI manages the observatory through its own community-based oversight and users committees. The NRAO director reports to the president of AUI. Oversight of the international ALMA project is vested in the ALMA Board, which includes a member from NSF; coordination and management of the merged international efforts are the responsibility of the Joint ALMA Observatory (JAO) whose staff includes an ALMA

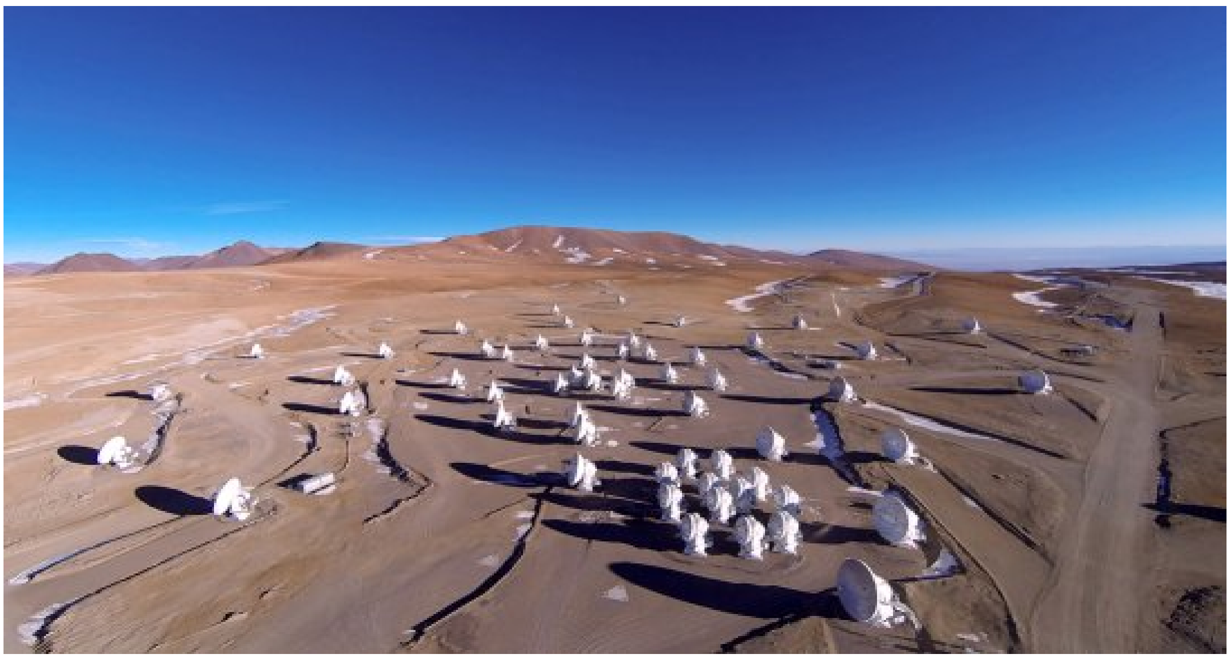
[25] https://public.nrao.edu/

director. An international ALMA review committee advises the ALMA Board.

- Reviews: NSF conducts annual reviews of the NRAO Program Operating Plan and strategic planning documents, ALMA operations, and the AUI Management Report. A Business Systems Review was conducted in FY 2012.

Renewal/Recompetition/Termination

Following a solicitation issued in FY 2014 (NSF 14-568), management and operation of NRAO, including ALMA, was competed and the National Science Board authorized a cooperative agreement with AUI for the period October 1, 2016 through September 30, 2026.



The Atacama Large Millimeter/submillimeter Array (ALMA) is in science operations following the completion of construction in 2015. ALMA, an international partnership between North America, Europe, and East Asia, provides orders-of-magnitude improvement in observing sensitivity and image quality over previous facilities. *Credit: NRAO/AUI.*

NATIONAL SOLAR OBSERVATORY **$20,000,000**

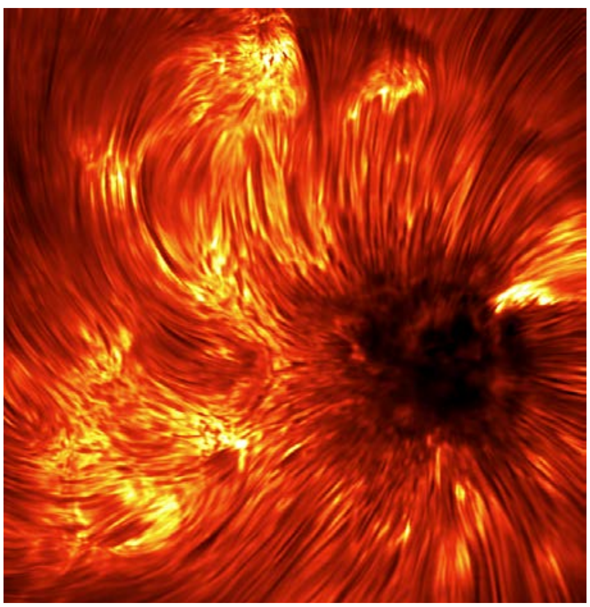
+$1,500,000 / 8.1%

National Solar Observatory
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change over FY 2016 Estimate Amount	Change over FY 2016 Estimate Percent
$13.00	$18.50	$20.00	$1.50	8.1%

The FY 2017 Budget Request for the National Solar Observatory (NSO) is $20.0 million. This is a $1.50 million (8.1 percent) increase above the FY 2016 Estimate and includes a one-time request to partially fund a Remote Operations Building (ROB) for the Daniel K. Inouye Solar Telescope (DKIST), should an ongoing environmental review process select this alternative. This increase also marks the continuation of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate DKIST. This profile will fund the development of the DKIST science operations and data center concepts in preparation for full DKIST operations expected to begin in 2019.

As a Federally Funded Research and Development Center (FFRDC), NSO currently operates facilities in New Mexico and Arizona as well as a coordinated worldwide network of six telescopes specifically designed to study solar oscillations. NSO also provides leadership to the solar community through management of the construction of DKIST. (See the Major Research Equipment and Facilities Construction (MREFC) chapter for more information.) NSO makes available to qualified scientists the world's largest collection of optical and infrared solar telescopes and auxiliary instrumentation for observation of the solar photosphere, chromosphere, and corona. NSO also provides routine and detailed, synoptic solar data used by individual researchers and other government agencies through the NSO Digital Library. NSO data are also made available to the user community via the Virtual Solar Observatory.


The chromospheric emission above a sunspot as traced by the Ca II line at 854.2 nm. Image taken with the IBIS instrument on the Dunn Solar Telescope. *Credit: K. Reardon, NSO.*

NSO telescopes are open to all astronomers regardless of institutional affiliation based on peer-reviewed observing proposals. In FY 2015, 57 unique observing programs from 17 U.S. and 13 foreign institutions were carried out using NSO facilities. Students were involved in 21 percent of these programs, which included five Ph.D. thesis projects. Nearly 18 terabytes of NSO synoptic data were downloaded from the NSO Digital Library, with approximately 37 percent of downloads coming from U.S. science institutions (.gov, .edu, and .mil), nine percent from other U.S. sources (.com, .net, etc.), and the remaining 54 percent of downloads coming from international sources. NSO employed approximately 120 staff members in FY 2015, including 65 FTEs employed on the DKIST construction project funded via the MREFC account as mentioned above.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New*

Horizons in Astronomy and Astrophysics,[26] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences within the Directorate for Mathematical and Physical Sciences (MPS/AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges,*[27] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

Prior to receiving the PRC report, NSF had instructed NSO to begin divestment of the facilities on Kitt Peak, including the McMath-Pierce solar telescope and the Vacuum Tower (no longer in use), thereby accelerating the already-planned divestment by a few years. The PRC endorsed this decision. The PRC recommended continued operation of the Dunn Solar Telescope (DST) through 2017 and a 50 percent reduction in funding of the NSO synoptic program. At present, the plan is for the McMath-Pierce telescope to be divested to a small university-based consortium, with short-term transition funding provided by NSF as part of the NSO request. A university-based consortium is seeking to support continued operations of the McMath-Pierce at a minimum level beyond FY 2017; however, this consortium has yet to secure the funding necessary to take over operations of the telescope. Active partnership discussions are also under way for continued operations of the DST located at NSO's Sacramento Peak facility. A consortium led by New Mexico State University has shown interest in taking over limited operations of the facility, and NSF is actively working with the consortium in this partnership.

In FY 2014, the NSF contracted with a general engineering firm to produce divestment studies that will provide baseline structural, historical, and environmental surveys of the McMath-Pierce telescope and the various NSO facilities on Sacramento Peak. The purpose of these studies is twofold. First, the studies will serve to inform NSF and potential partners of the current state of the facility. Second, the study will explore various divestment options and provide an assessment of the potential costs involved. NSF expects the engineering study to be completed early in calendar year 2016. After viable options are identified, NSF will embark on formal reviews (FY 2016) to evaluate the impacts of these alternatives, including partnership opportunities that could involve further environmental assessments.

Total Obligations for NSO

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	ESTIMATES[1] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
NSO Base Operations	$7.78	$6.75	$5.74	$4.73	$3.70	$3.82	$3.92	$4.04
NSO Education & Public Outreach	0.22	0.25	0.26	0.27	0.30	0.31	0.32	0.33
DKIST Operations[2]	5.00	9.00	14.00	14.00	16.50	17.01	17.54	18.08
GONG Refurbishment	-	2.50	-	-	-	-	-	-
Total, NSO	**$13.00**	**$18.50**	**$20.00**	**$19.00**	**$20.50**	**$21.14**	**$21.78**	**$22.45**

Totals may not add due to rounding.

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2024.

[2] Total Research and Related Activities account funding for DKIST consists of $14.0 million in FY 2017 funded through NSO, plus $2.0 million per year in FY 2011 to FY 2020 for cultural mitigation activities as agreed to during the compliance process that is not funded though NSO. See the MREFC chapter for more information on DKIST.

[26] www.nap.edu/catalog.php?record_id=12951

[27] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Partnerships and Other Funding Sources: The managing organization for NSO is the Association of Universities for Research in Astronomy, Inc. (AURA), which comprises 39 U.S. member institutions and seven international affiliate members. NSO partners include the U.S. Air Force, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and industrial entities. Other funding entities include universities and institutes, which collaborate with NSO on solar instrumentation development and on the design and development of DKIST. New telescopes, instrumentation, and sensor techniques are developed through industry sub-awardees in aerospace, optical fabrication, and information technology.

Previously, the Air Force was the most significant source of external funding to NSO; however, with NSO's involvement in the Sacramento Peak facility winding down and the relocation of personnel to Boulder, CO, Air Force support for NSO operations has been reduced to zero for FY 2016 and into the foreseeable future. In addition, the Air Force Weather Agency (AFWA), which was previously a supporter of the NSO's Global Oscillations Network Group (GONG) facility, is no longer contributing to the funding of GONG operations. Due to the increasing national and international awareness of the impacts of space weather on critical infrastructure and society in general, the importance of operational space weather forecasting has become apparent to U.S. policy makers. This importance was highlighted by the recent (October 29, 2015) rollout of the National Space Weather Strategy[28] and the associated National Space Weather Action Plan.[29] Space weather forecasting requires both accurate models of the heliospheric environment and precise observational data inputs to those models. The NSO's GONG program provides operational data products on a routine basis that are used as inputs to predictive space weather models from AFWA and the NOAA Space Weather Prediction Center (SWPC). The FY 2016 plan for NSO includes a one-time $2.50 million investment in GONG to increase its robustness for future space weather predictions.

NSO Base Operations, $5.74 million, $1.01 million below the FY 2016 Estimate: NSO Base Operations includes operations at Sacramento Peak Observatory in Sunspot, New Mexico, facilities based on Kitt Peak, Arizona, and the world-wide NSO Integrated Synoptic Program consisting of the GONG array and the SOLIS (Synoptic Optical Long-term Investigations of the Sun) telescope. In addition, the NSO Directorate recently relocated to the campus of the University of Colorado in Boulder. Boulder has become a national center of solar and space physics. This relocation places the NSO headquarters squarely in the center of the solar community. The funding profile for NSO Base Operations is ramping down in anticipation of the divestment of redundant facilities by the end of 2017. By the end of this ramp, NSO Base Operations will fund NSO Directorate activities as well as the NSO synoptic program operations at a steady level of about $4.0 million ($2.0 million each) per year.

DKIST Operations, $14.0 million, $5.0 million above the FY 2016 Estimate: Support for DKIST operations is through the Research and Related Activities account (R&RA), while DKIST construction support is through the MREFC account. (See the MREFC chapter for more information on construction.) The FY 2017 Request for DKIST Operations represents the third year of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate DKIST. This profile will fund the development of the DKIST science operations and data center concepts in preparation for full DKIST operations, which is expected to begin in 2019.

The Request also includes $2.50 million above previous forecasts for partial funding of a DKIST Remote Operations Building (ROB); the remainder of the approximately $6.20 million required for the ROB will be recovered from reduced lease costs in FY 2017 and from deferring data-center hardware purchases until later in the operations development. The need for an operations facility located on Maui was identified in the early stages of DKIST development. The ROB would act as an extension of the NSO Data Center in

[28] www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf
[29] www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatheractionplan_20151028.pdf

Boulder, CO whereby the ROB receives, buffers, and transmits the estimated 12 terabytes per day gathered by the DKIST facility and will serve as a base of operations for NSO personnel. In FY 2015, AURA demonstrated to NSF that construction of a dedicated ROB would result in significant savings to the Federal government as compared to leasing space over the planned 45-year lifetime of DKIST. Should an ongoing environmental review process select the ROB alternative, it would result in reduced total operations costs by eliminating out-year lease payments.

Education and Public Outreach, $260,000, $10,000 above the FY 2016 Estimate: NSO supports U.S. education goals by promoting public understanding and support of science and by providing education and training at all levels. NSO introduces undergraduate students to scientific research by providing stimulating environments for basic astronomical research and related technologies through NSF's separately funded Research Experiences for Undergraduates (REU) program. NSO has diverse education programs, including teacher training and curriculum development, visitor centers, and a web-based information portal at www.nso.edu.

Management and Oversight

- NSF Structure: An NSF program officer in AST provides continuing oversight, including consultation with an annual NSF program review panel. The program officer makes use of detailed annual program plans, annual long-range plans, quarterly technical and financial reports, and annual reports submitted by NSO as well as attending AURA Solar Observatory Council meetings. The latter committee is formed from the national solar physics community and provides a window into community priorities and concerns. The AST program officer works closely with other offices at NSF, particularly the Division of Acquisition and Cooperative Support, the Office of General Counsel, and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- External Structure: AURA is the managing organization for NSO. The NSO director reports to the president of AURA, who is the principal investigator on the current NSF cooperative agreement. AURA receives management advice from its Solar Observatory Council, composed of members of its scientific and management communities. NSO uses visiting and users committees for the purposes of self-evaluation and prioritization. The visiting committee, composed of nationally prominent individuals in science, management, and broadening participation, reviews for AURA all aspects of the management and operations of NSO. The users committee, composed of scientists with considerable experience with the observatory, reviews for the NSO director all aspects of NSO that affect user experiences at the observatory.
- Reviews: In addition to reviews held mid-way through all cooperative agreements, NSF conducts periodic and ad hoc reviews, as needed, by external committees. A Business Systems Review was held in spring 2013. A re-baseline review for the DKIST project, described in the DKIST narrative in the MREFC chapter, was held in October 2012. An extensive review of NSO was conducted in January 2014 as part of the renewal of the cooperative agreement for management and operations (see below).

Renewal/Recompetition/Termination

On August 14, 2014, the National Science Board (NSB) authorized a renewed cooperative agreement with AURA for management and operation of NSO for a period of 10 years from October 1, 2014 through September 30, 2024. Concurrent with the NSB approval process, the AURA proposal for NSO management and operations underwent an extensive budgetary review by personnel from NSF, which lasted from March 2014 through May 2015. This extended period of the review required the extension of the existing cooperative agreement through May 31, 2015. Upon completion of the review, the renewed cooperative agreement between the NSF and AURA was put into place June 1, 2015.

OTHER ASTRONOMICAL FACILITIES

$11,500,000
+$11,500,000 / NA%

Other Astronomomical Facilites
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017[1] Request	Change over FY 2016 Estimate Amount	Percent
-	-	$11.50	$11.50	N/A

[1] Beginning in October 2016, funding for these facilities as stand-alone entities will be provided separately from National Radio Astronomy Observatory (NRAO) funding.

Prior to FY 2017, the National Radio Astronomy Observatory (NRAO) operated major radio telescopes at the Green Bank Observatory (GBO) in Green Bank, West Virginia, including the Robert C. Byrd Green Bank Telescope (GBT), and at 10 telescope array sites spanning the U.S. from the Virgin Islands to Hawaii, together constituting the Very Long Baseline Array (VLBA). This narrative presents the FY 2017 Budget Request for GBO and VLBA.

In 2010, the National Research Council conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics,*[30] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges,*[31] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

In 2012, the Portfolio Review Committee recommended divestment of the GBT and VLBA from AST funding because of a less compelling mapping than other facilities onto the science questions of the 2010 decadal survey. As announced in a Dear Colleague Letter, NSF 13-074,[32] NSF partitioned GBT and VLBA from the competition for NRAO management and operations, increasing flexibility for exploring cost-efficient operational models and sustainable partnerships for GBO (comprising GBT and the Green Bank site and facilities) and VLBA. Existing partnerships are described below, and additional partner discussions with governmental and non-governmental entities are ongoing. In FY 2016, an engineering firm is producing feasibility reports for divestment alternatives of both GBO and VLBA; these reports include baseline structural and environmental surveys of GBO and VLBA. Should viable options be identified and the decision made to divest, NSF will embark on formal reviews (in FY 2016 and FY 2017) to evaluate environmental impacts of these alternatives, including potential impacts of partnership opportunities.

In FY 2016, AST anticipates receiving a proposal from Associated Universities, Inc. (AUI) to continue management and operation of GBO and VLBA in FY 2017 and FY 2018, separate from the management and operation of NRAO. Previously, the obligations for GBO and VLBA were heavily matrixed and not separable from the overall obligation for NRAO. Hence, NSF funding for GBO and VLBA in years prior

[30] www.nap.edu/catalog.php?record_id=12951
[31] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[32] http://nsf.gov/pubs/2013/nsf13074/nsf13074.jsp

to FY 2017 are included in the NRAO narrative within the Facilities chapter of the FY 2017 Budget Request. This table below does not separate funding for GBO and VLBA, since the detailed breakdown between the two is the subject of the expected proposal and will depend on anticipated and achieved partnerships. Notional funding beyond FY 2018 is shown as flat, although it is expected that the out-year numbers will change significantly as partnerships evolve.

Total Obligations for Green Bank and VLBA

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request[1]	ESTIMATES[2] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Operations & Maintenance	-	-	$11.50	$11.85	$11.85	$11.85	$11.85	$11.85

[1] Beginning in October 2016, funding for these facilities as stand-alone entities will be provided separately from National Radio Astronomy Observatory (NRAO) funding.

[2] Outyear funding estimates are for planning purposes only. The operating award (currently under review) for GBO and VLBA is expected to run through the end of September 2018.

Partnerships and Other Funding Sources: In FY 2016, GBO and VLBA receive about $6.0 million from other sources, roughly two-thirds from non-federal partners and one-third from other federal sources. Many of these partnerships involve guaranteed allocations of observing time on the GBT or VLBA. In FY 2017, the GBO partnership with the radio astronomy space mission is expected to end, but other partner discussions are ongoing.

Education and Public Outreach: The Green Bank Science Center at GBO now about 40,000 visitors per year and carries out dedicated programs for professional educators and school groups. The continuation of this program in the future will be one of the subjects of the anticipated proposal from AUI.

GBO and VLBA Operations and Maintenance, $11.50 million: This supports direct telescope operations, including maintenance, infrastructure, telescope management, and Education and Public Outreach.

Management and Oversight

- NSF Structure: In consultation with community representatives, a dedicated AST program officer carries out continuing oversight and assessment for GBO and VLBA by making use of detailed annual program plans, technical and financial reports, and annual reports submitted to NSF. The AST program officer attends AUI governance and advisory committee meetings. AST works closely with other NSF offices, such as the Office of General Counsel, the Office of International Science and Engineering, the Division of Acquisition and Cooperative Support, and the Large Facilities Office in the Office of Budget, Finance, and Award Management.
- External Structure: Management is via a cooperative agreement with AUI. AUI manages the observatories through its own community-based oversight and users committees. GBO and VLBA directors will report directly to AUI.
- Reviews: NSF will review the anticipated proposal for FY 2017 and FY 2018 funding and conducts annual reviews of the Program Operating Plan and reports.

Renewal/Recompetition/Termination

GBO and VLBA are currently supported through the cooperative agreement for NRAO, which ends on September 30, 2016. A six month transition award, starting on April 1, 2016, will provide for implementation costs of separating GBO and VLBA from NRAO. On October 1, 2016, this Request will provide for GBO and VLBA as stand-alone entities through an award (under review) expected to run through September 2018. Management of GBO and VLBA after FY 2018 will be based on the outcome of partnership discussions and the engineering/environmental review process described above.

OTHER FACILITIES FUNDING

Major Research Equipment and Facilities Construction Account Projects
The MREFC account supports the acquisition, construction, and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Projects supported by this account are intended to extend the boundaries of technology and open new avenues for discovery for the science and engineering community. Initial planning and design, and follow-on operations and maintenance costs of the facilities are provided through the Research and Related Activities account (R&RA) and Education and Human Resources (EHR) account.

For information on projects funded through this account, refer to the MREFC chapter of this Budget Request.

Preconstruction Planning
Within the R&RA account, funds are provided for preconstruction studies for prospective large facility projects. This funding generally supports such activities as design, cost estimates, and other actions that prepare potential projects for oversight review, agency decision milestones, and potential implementation.

NSF-WIDE INVESTMENTS

CYBER-ENABLED MATERIALS, MANUFACTURING, AND SMART SYSTEMS (CEMMSS) $257,120,000 +$820,000 / 0.3%

Overview

The Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) investment aims to integrate a number of science and engineering activities across NSF, including breakthrough materials, advanced manufacturing, and smart systems, which includes robotic, cyber-physical and autonomous systems. These investments are in response to the Materials Genome Initiative (MGI) and Advanced Manufacturing Partnership (AMP). Through CEMMSS-funded research, materials with unique properties and functionality are being discovered and developed more reliably and efficiently via the integration of theory, modeling and simulation, data analytics, and experiments. These new materials can in turn be fashioned into objects, structures, and systems embedded with computational intelligence, thereby transforming today's static systems, processes, and edifices into adaptive, pervasive, and smart systems through the use of advanced manufacturing strategies.

The smart systems of tomorrow and the materials from which they will be composed will vastly exceed those of today in terms of adaptability, autonomy, functionality, efficiency, reliability, safety, usability, recoverability, and recyclability. These smart systems will achieve high levels of autonomy, and will be able to act independently and intelligently in dynamic, uncertain, and unanticipated environments. These advances have the potential to accelerate scientific and engineering discoveries to address key national and societal challenges critical to U.S. security and competitiveness.

Total Funding for CEMMSS

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$269.83	**$256.30**	**$257.12**

Goals

Goal 1: Science and Engineering

CEMMSS is establishing a scientific base, a codified knowledge base, and shared principles for designing, manufacturing, and deploying cyber-enabled smart engineered systems and advanced materials.

Goal 2: Education, Workforce Development, and Community Building

CEMMSS investments are leading to the education of a cadre of high-caliber disciplinary and interdisciplinary researchers and developing a vibrant workforce so as to ensure a pipeline of talent and a growing community in these critical areas.

Goal 3: Research Infrastructure Development

CEMMSS is developing the critical research infrastructure that can be used to discover, test, refine, and validate the advanced materials, designs, and manufacturing and development methods so as to enable the deployment of smart systems.

Approach

The CEMMSS framework of bringing together researchers focused on breakthrough materials, advanced manufacturing, and smart systems is increasing collaboration and communication among these research communities. This is leading to enhanced disciplinary and interdisciplinary research. CEMMSS funds research that couples modeling and theory with experimentation, thereby shortening the time and resources required for the discovery of new materials, new approaches to advanced manufacturing, and novel advances in smart and autonomous systems. Such efforts will aid in the transformation of static systems, processes, and edifices into adaptive, widespread smart systems with embedded computational intelligence that can sense, adapt, and react. Success in CEMMSS will drive transformations that address the pressing technological challenges facing the Nation and promote U.S. economic competitiveness.

Programmatic

CEMMSS comprises a research portfolio that synchronizes activities across three main research areas – breakthrough materials, advanced manufacturing, and smart systems – and encourages interdependencies and common research elements to surface and be exploited at each subsequent stage of the evolution of the program. The CEMMSS portfolio includes the following specific investment areas:

- ***Breakthrough materials***: This investment focuses on accelerating the discovery and development of the materials required for meeting societal needs and finding paths for sustainable and scalable manufacturing technologies. CEMMSS investments in this area will pursue a research approach in which computation, data analytics, and theory are combined with research in materials synthesis and characterization in a collaborative and iterative manner.
- ***Advanced Manufacturing***: CEMMSS investments in this area leverage both disciplinary and topical mechanisms to advance knowledge for the production of novel products through processes that depend on the coordination of information, automation, computation, networking, or other emerging scientific capabilities.
- ***Smart Systems***: This investment leverages synergistic advances made in the earlier years of CEMMSS to place an emphasis on smart systems. It supports basic research on both next-generation robotics and cyber-physical systems, as well as an emerging emphasis on the fundamental science of intelligent, autonomous systems. The supported fundamental research will enable new functionalities and provide the next generation of products, services, and manufacturing that vastly exceed those of today in terms of adaptability, functionality, reliability, safety, usability, and recyclability in dynamic, uncertain, and unanticipated environments.

Organizational

CEMMSS leadership is shared across the relevant division directors in the Biological Sciences, Computer and Information Science and Engineering (CISE), Engineering (ENG), and Mathematical and Physical Sciences (MPS) directorates. The CEMMSS coordination team comprises program directors from these directorates, and this group is charged with developing and implementing the suite of CEMMSS activities. The team is also working with internal and external program evaluation experts to develop a set of metrics by which program progress can be assessed over time.

Scope

Numerous CEMMSS interdisciplinary connections exist at NSF. Many are pairwise and expanding, such as robotics and manufacturing; materials and manufacturing; cyber-physical systems and robotics; cyber-physical systems and manufacturing materials; cyber-physical systems and advanced manufacturing; manufacturing and the biological sciences; robotics and the biological sciences; and advanced manufacturing and technician education. NSF has sponsored, and will continue to hold, community-building workshops. The intention is to drive new research directions, and this is being achieved through a combination of new solicitations and Dear Colleague Letters (DCLs). CEMMSS currently includes many interagency activities, and new cross-agency partnerships are continuously being developed. Industry partnerships also are a key element in CEMMSS's success; industry and venture capital groups are invited to workshops and principal investigator (PI) meetings. CEMMSS presents a unique opportunity to accelerate integrative research and educational activities. The interaction of research ideas that is promoted by CEMMSS multiplies their impact across multiple research communities.

Investment Framework

CEMMSS Funding by Directorate

(Dollars in Millions)

Directorate	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$4.99	$5.48	$5.48
Computer and Information Science and Engineering	89.00	90.98	92.50
Engineering	110.77	110.00	112.00
Mathematical and Physical Sciences	65.07	49.84	47.14
Total	**$269.83**	**$256.30**	**$257.12**

Totals may not add due to rounding.

FY 2015– FY 2016

The specific CEMMSS investments in Advanced Manufacturing, Designing Materials to Revolutionize and Engineer our Future (DMREF), and Smart Systems, including investments in Cyber-Physical Systems (CPS) and the National Robotics Initiative (NRI), continued to focus on increased integration of the highest-priority areas, such as those related to materials and manufacturing, and developing smart systems. NSF is continuing to support NRI, CPS, and DMREF, as well as core research programs, focused on the highest-priority areas related to advanced manufacturing.

NSF continued to fund the Scalable Nanomanufacturing (SNM) program in FY 2015. The SNM program funds interdisciplinary projects that present explicit strategies for transitioning advanced nanomanufacturing methods into practice. In FY 2016, NSF is continuing to support research in SNM for manufacture of demonstrably useful nano-enabled products in high volume and at low cost.

Cybermanufacturing has become an important area of focus in advanced manufacturing. In FY 2015, ENG and CISE jointly issued a DCL on Cybermanufacturing Systems to encourage collaborative Early-Concept Grants for Exploratory Research (EAGER) for novel, early-stage, multidisciplinary, and high-risk/high-reward research on cybermanufacturing systems. ENG and CISE are jointly funding a workshop to be held in FY 2016, *Enabling Composable and Modular Manufacturing through Abstractions: Where Computer Science Meets Manufacturing*, to advance this emerging research area further. In FY 2016, NSF is continuing to emphasize investments in cybermanufacturing systems. Such investments will enable research on the networked integration of manufacturing machines, equipment, and systems into an increasingly accessible manufacturing service infrastructure. This activity will leverage investments through the FY 2015 DCL and existing programs within ENG, as well as previous and ongoing investments in cross-directorate activities including NRI and CPS.

Advanced biomanufacturing also emerged as an important emphasis research area in the overall portfolio of advanced manufacturing research. ENG, MPS, BIO, and the Department of Energy (DOE) previously jointly funded a National Academy of Sciences (NAS) study on the Industrialization of Biology. The study focused on the research, education, and infrastructure needs to enable advances in biomanufacturing, including the commercialization processes for biologically-based manufacturing of high-value products. NAS published the final report from this study in FY 2015.[1] Additionally, NSF and the European Commission sponsored one in a series of community-driven workshops on synthetic biology standards in March 2015; this workshop was attended by representatives from the National Institute of Standards and Technology (NIST) and the Defense Advanced Research Projects Agency (DARPA). NIST also sponsored a Synthetic Biology Standards Workshop in March 2015. This workshop supported the development of

[1] www.nap.edu/catalog/19001/industrialization-of-biology-a-roadmap-to-accelerate-the-advanced-manufacturing

standards to enable data sharing and automation in advanced biomanufacturing and engineering biology.[2]

Processes with cells as products present major engineering challenges, and new therapies and cell-based products may depend critically on robust and reliable manufacturing approaches at the cellular level. In FY 2015, ENG released a DCL that called for EAGERs to support research that addresses these critical aspects of cellular biomanufacturing. In FY 2016, NSF is continuing to support research in advanced biomanufacturing; this research will focus on studying theories and technologies of design, engineering, and manufacturing of bio-related (natural or synthetic) products, such as cells and cell-based therapeutic products (e.g., individualized tissues and organoids), or devices with biomaterials and/or cells as components. NSF will leverage the Biomedical Engineering and Biotechnology and Biochemical Engineering programs within ENG, as well as the Systems and Synthetic Biology program within BIO, and build on groundbreaking discoveries, many of which have been supported by NSF in the past, such as three-dimensional additive manufacturing, genome editing, systems and synthetic biology, stem cell biology, computational modeling, micro- and nano-fabrication, and tissue engineering and regenerative medicine. These efforts offer, in part, the promise of enabling the manufacturing of products for low-cost therapeutic research, personalized therapeutic products, and high-value chemicals and materials.

Accelerating U.S. Advanced Manufacturing, the October 2014 report produced by the Steering Committee of the Advanced Manufacturing Partnership 2.0 (AMP 2.0) for the President's Council of Advisors on Science and Technology (PCAST),[3] calls for the creation of a technology-focused consortium to provide coordinated private-sector input on national advanced manufacturing technology research and development priorities. In response to the report, NSF and NIST jointly issued a solicitation to establish the Consortium for Advanced Manufacturing Foresights (the "Consortium") in FY 2015. NSF and NIST made the award to establish the Consortium in early FY 2016 to the Alliance for Manufacturing Foresight (MForesight), and commissioned two rapid reports with the goal of identifying emerging technologies with crosscutting appeal, opportunities for public-private partnerships, and barriers to commercialization in the areas of advanced biomanufacturing. Additionally, ENG and CISE collaborated on a DCL through the Industry/University Cooperative Research Centers (I/UCRC) program to support collaborative clusters among I/UCRC in response to AMP 2.0. ENG and BIO funded a planning grant for an I/UCRC in the area of advanced biomanufacturing in response to a FY 2014 DCL, and full proposals for an advanced biomanufacturing center are being evaluated in FY 2016. The goal is to create a cross-disciplinary, cross-sector portfolio of research projects that hold the potential to catalyze technology breakthroughs and advance national priorities, particularly in advanced manufacturing.

The DMREF program developed a multi-directorate solicitation in FY 2015 for proposals that integrate theory, simulation, and/or cyber-enabled data analytics with synthesis and characterization experiments in an iterative manner. This research will accelerate new materials discovery, design, and innovation. The solicitation was revised for FY 2016. Additionally, to spotlight opportunities for mathematical sciences research in connection with DMREF, NSF supported a Symposium on Mathematical and Computational Aspects of Materials Science in FY 2015 at the Conference on Computational Science and Engineering of the Society for Industrial and Applied Mathematics (SIAM).[4] In FY 2016, DMREF will continue through a joint solicitation spanning MPS, ENG, and CISE.

Through FY 2015, NSF investments in smart systems were primarily in the areas of NRI and CPS. In FY 2015, NSF and the Office of the Secretary of Defense (OSD) signed an MOU to allow participation of the Department of Defense (DOD) in NRI. DARPA joined NRI, with a particular interest in validation of simulation methods; this topic is important to many manufacturing problems. The DOD/DARPA

[2] https://jimb.squarespace.com/sbsc-0315-workshop-report
[3] www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/amp20_report_final.pdf
[4] http://connect.siam.org/nsf-siam-symposium-on-mathematical-and-computational-aspects-of-materials-science-at-cse15/

participation in NRI adds to the existing partnerships with the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), and U.S. Department of Agriculture (USDA). In FY 2016, DOE joined the NRI solicitation, and plans to fund research that focuses on the handling of high-hazard, high-consequence materials. Meanwhile, in the case of CPS, NSF previously partnered with the Department of Homeland Security (DHS) and the U.S. Department of Transportation to broaden the scope of the CPS solicitation. In FY 2015, the solicitation further broadened to include the participation of NASA and NIH. USDA is joining the CPS solicitation in FY 2016.

In FY 2015, NRI convened a workshop encouraging collaboration between the research communities of locomotion and manipulation, particularly in areas of planning, control, perception, and design. NRI ran a PI meeting that included industry participation, enabling PIs to discern gaps and promote exchange in research collaborations related to manufacturing. NSF also sponsored technical workshops in many of the key areas of CPS, including cybersecurity for CPS, critical research problems related to time with respect to CPS, and cloud computing for CPS. Additionally, NSF previously funded an NAS study on CPS education, seeking to understand current and future needs in education for CPS. NAS convened two workshops, including one in FY 2015, and issued an interim report in FY 2015.[5] A final report is anticipated in FY 2016. NSF also continued to support the CPS Virtual Organization (CPS VO), which is a broad community of interest for CPS researchers and developers. In FY 2015, NSF funded a proposal that will support the CPS VO as it evolves to a long-term, sustainable, community organization.

NSF held a workshop in FY 2015 to bring together researchers in the robotics and CPS communities to develop a set of foundational problems common to the two communities, as well as related challenges in autonomous systems. In FY 2016, NRI and CPS are continuing to support workshops to connect researchers across the robotics and CPS communities. During these meetings, attendees are developing a set of foundational research questions that will serve as a source of synergy between NRI and CPS, with an eye toward smart and autonomous systems. NSF is leveraging synergistic advances made in the earlier years of CEMMSS in NRI and CPS to place an emphasis on smart and autonomous systems in future years; these investments will include the traditional NRI and CPS areas, as well as an increased focus on the science of intelligent, autonomous systems.

In FY 2016, NSF is holding workshops that explore the research opportunities with NRI, CPS, and smart and autonomous systems in emerging research and application areas, including Smart and Connected Communities and the Internet of Things. NSF is holding workshops on new research advances needed in the technical and socio-technical understanding of the science of autonomy. These workshops are also helping to identify and pursue research gaps in the NSF portfolio for smart and autonomous systems. NSF is continuing to engage additional agency partners in joint solicitations for NRI, CPS, and the emerging area of smart and autonomous systems. For example, the CPS Strategic Steering Group will explore partnerships with mission agencies to facilitate translation of NSF-funded research into further development and deployment activities.

In FY 2016, NRI and CPS are increasing their focus on Transition to Practice (TTP), while continuing to maintain strong foundational research emphases. NRI is conducting a joint academic-industry-government workshop on evaluating alternative means of TTP. CPS is focusing on funding an I/UCRC, and on holding a session at the annual CPS PI meeting describing programs that enable TTP and showcasing successful CPS TTP efforts. NSF is further identifying opportunities for its researchers to engage with interagency-supported Institutes for Manufacturing Innovation.

[5] http://sites.nationalacademies.org/cstb/CurrentProjects/CSTB_084351

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- NSF will continue to support and emphasize research in cybermanufacturing systems to enable the networked integration of manufacturing machines, equipment, and systems into an increasingly accessible manufacturing service infrastructure. These investments will build upon initial activities within the advanced manufacturing, NRI, and CPS programs.
- NSF will continue to invest in the SNM program and advanced biomanufacturing.
- NSF will regularly perform gap and opportunity analysis of emerging research areas through support for workshops and studies, and through the Consortium for Advanced Manufacturing Foresights. This analysis will allow for prioritization of advanced manufacturing research topics that should receive increased investments. Based on the initial reports delivered in FY 2016, NSF will target investments in advanced biomanufacturing.
- NSF will continue to support DMREF through an annual solicitation. NSF will invest in infrastructure needs in support of DMREF.
- The most effective activities of FY 2016, as identified through evaluation of the NRI and CPS programs, will be continued and expanded in FY 2017, with an emphasis on areas of autonomous, intelligent systems.
- NSF will update the NRI and CPS solicitations, with new emphasis areas and/or solicitations based on gap analysis results and community input, especially relating to autonomous, intelligent systems. These solicitations will also be updated to suggest engagement of projects in cross-disciplinary workforce development (academic and industrial) as a key consideration in evaluating the broader impacts criterion. NSF will pursue involvement of additional agencies and international partners in NRI, CPS, and smart and autonomous systems appropriate to the program objectives.
- Building on the successes of the CPS and NRI programs, NSF will provide initial support for a new investment in Smart & Autonomous Systems. This investment area will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. This research activity will accelerate the transformation of static systems, processes, and edifices into intelligent, autonomous systems, such as those that can sense, learn, and adapt.
- NSF will sponsor workshops to examine the social, behavioral, and economic research issues associated with the design and deployment of smart and autonomous systems, such as smart buildings, smart communities, automated ground transportation, automated flight systems, disaster response and recovery, automation and extra-planetary science and exploration, automation and agriculture, construction automation, automated in-home services, and automation for law enforcement.
- PI meetings in NRI and CPS will continue, with areas of focus to include advancing cross-project interaction and collaboration; establishing safety standards and risk metrics; and planning for project transitions to partners, other projects, and industry.
- NSF will continue to hold, with its partner federal agencies, annual MGI/DMREF PI meetings.
- NSF will sponsor smart and autonomous systems challenges and competitions on topics requiring solutions and implementations that call upon multidisciplinary CEMMSS knowledge and systems integration. Such activities will involve existing NRI and CPS participants, as well as new participants in smart and autonomous systems.
- NSF will develop plans for data, software, and physical infrastructure for smart and autonomous systems, including NRI and CPS, with an emphasis on engaging the community through workshops in a discussion on requirements for such infrastructures and incentives for their use. NSF will fund at least two proposals in community testbed/infrastructure for NRI, CPS, and/or smart and autonomous systems.
- NSF will continue integration of functional components developed in the NRI, CPS, and smart and autonomous systems areas; promote designs for specific knowledge domains (e.g., manufacturing, healthcare); and promote high-risk, breakthrough applications and testbeds not previously possible.

FY 2018

While the NSF-wide CEMMSS investment will conclude at the end of FY 2018, the collaborative research activities of CEMMSS are expected to continue. Some specific investments will be assimilated back into core programs within and across participating directorates, while others will continue as crosscutting investments that span multiple NSF divisions and directorates. NSF will continue to develop several comprehensive, integrated programs across CEMMSS focus areas, such as cyber-manufacturing, advanced materials, and smart systems as well as further develop the new investment made in FY 2017 in Smart and Autonomous Systems. These investments will encourage new connections, discoveries and/or emerging fields of science and engineering.

It is expected that at the end of CEMMSS there will be evidence of an integrated and thriving ecosystem of cyber-enabled systems and advanced materials; improved interdisciplinary education based on longitudinal study of education outcomes; and advanced research infrastructure used by CEMMSS scientists and engineers. Such outcomes are in line with the overall goals of this investment.

Evaluation Framework

NSF engaged the Science and Technology Policy Institute (STPI) in FY 2012 to assist with the development of a plan for an impact assessment of the CEMMSS initiative. This formulation has entailed discussions with CEMMSS management, including division directors, as well as CEMMSS program directors. These discussions are also helping to formulate appropriate synergistic working groups spanning Smart Systems (including NRI, CPS, and smart and autonomous systems), Advanced Manufacturing, DMREF, and other related CEMMSS activities. The approach outlined below is being followed for CEMMSS program evaluation and assessment:

- A portfolio analysis was conducted to understand the scope and scheme of the overall CEMMSS initiative. The first step entailed gathering information and understanding the baseline portfolio, stakeholders, and related activities that NSF currently supports in the CEMMSS area. This included examining the current state of research in the research subfields and analyzing the various recommendations from federal advisory boards and the stakeholder communities on how future investments in CEMMSS areas should be focused.
- The results of the portfolio analysis are providing analytical input to support the CEMMSS coordination team's efforts to bring the community together to develop the interdisciplinary research questions for CEMMSS.
- STPI developed a logic model to help NSF track progress toward the major scientific, educational, and infrastructure objectives of CEMMSS.
- Given the diversity of research communities under the CEMMSS umbrella, NSF is sponsoring multiple workshops to understand research challenges and opportunities. The results of these workshops are being used to identify a clear set of research challenges that will be used by NSF to guide the CEMMSS investment area going forward.

By the end of FY 2016, a report summarizing the portfolio analysis and evaluation feasibility study will be submitted to the CEMMSS coordination team.

The progress of the implementation of CEMMSS also was monitored and reviewed quarterly as part of an agency performance goal in FY 2014 and FY 2015. For more information about monitoring key program investments, see the FY 2015 Annual Performance Report in the Performance chapter.

CYBERINFRASTRUCTURE FRAMEWORK FOR 21ST CENTURY SCIENCE, ENGINEERING, AND EDUCATION (CIF21)

$100,070,000
-$32,350,000 / -24.43%

Overview

The Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) investment accelerates and transforms the processes and outcomes of scientific discovery and innovation by providing and supporting the use of advanced cyberinfrastructure that enables new functional capabilities in computational and data-enabled science and engineering across all disciplines.

Science, engineering, and education continue to be transformed by increasingly comprehensive and scalable cyberinfrastructure that bridges diverse scientific communities and brings together theoretical, computational, experimental, and observational approaches. Large volumes of research data are being generated by scientific instruments, observing systems, and mobile and embedded systems, as well as by publications, experiments, simulations, surveys and evaluations, and analyses. New and emerging data sources are also becoming available to the scientific community, through efforts such as digitizing collections and enhancing access to records and documents. In addition, scientists, using thousands of distributed scientific instruments, such as gene sequencers, sensors, and imaging devices, are generating many more small data archives and heterogeneous data sets at an unprecedented rate, creating the long tail of science, which is yet another data cyberinfrastructure challenge.

Complex scientific research problems, such as those being pursued through other NSF-wide investments such as Understanding the Brain (UtB) and Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS), require advanced computational models, methods, and algorithms, including innovative, robust, and sustainable software that turn raw data into knowledge and action. CIF21 constitutes a portfolio of activities that leverage ongoing cyberinfrastructure investments across NSF by coordinating and deploying common approaches and components to manage data and provide computational support to all areas of science and engineering while also developing new multidisciplinary research communities.

Although the CIF21 NSF-wide investment is sunsetting at the end of FY 2017, NSF will continue to support developing a pervasive cyberinfrastructure that enables research at unprecedented scales, complexity, resolution, and accuracy during the sunsetting period. In particular, some CIF21 investments will transition to a set ot focused activities in support of the Administration's National Strategic Computing Initiative (NSCI) as well as NSF's new Data for Scientific Discovery and Action (D4SDA) investment area.

Total Funding for CIF21

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$157.04	**$132.42**	**$100.07**

Goal

The goal of CIF21 is to enable the science and engineering research and education communities to gain new insights and investigate ever broader and more complex research questions through the use of advanced computing systems, software, innovative computational approaches, data systems and repositories, major research instruments, visualization systems, and other analytic tools and techniques that together comprise cyberinfrastructure. CIF21's cross-community and multi-pronged approach directs these investments along a path toward a comprehensive, integrated, sustainable, and secure cyberinfrastructure that accelerates research and education through new functional capabilities driven by recent transformations in computational and data-intensive science and engineering.

CIF21 has three specific objectives:

- To support foundational data and computational research and development, including use-inspired demonstrations;
- To enable world-class data, computational, and digital capabilities and services; and
- To ensure long-term sustainability and future growth for advanced cyberinfrastructure through building research communities with the right skills and breadth to be able to contribute to the many new and emerging cross-cutting research domains.

Approach

The vision of CIF21 is to catalyze new thinking, paradigms, and practices in science and engineering by fostering a pervasive cyberinfrastructure that enables research at unprecedented scales, complexity, resolution, and accuracy. This cyberinfrastructure aims to integrate and coordinate computation, data, and experiments in novel ways, nationally and internationally.

<u>Programmatic:</u>

CIF21 uses a combination of solicitations, Dear Colleague Letters (DCLs), and focused workshops to fund the research, development, and deployment of cyberinfrastructure and related applications. The ubiquity of cyberinfrastructure requires partnerships and joint collaborations with industry, other federal agencies and international groups. Principal Investigator (PI) meetings, conferences, and workshops reach out to new communities of researchers and educators.

<u>Organizational:</u>

The CIF21 organizational structure employs five interrelated groups to ensure that CIF21 continues to build upon NSF's history of providing leadership in the design, development, and use of the cyberinfrastructure required to transform science, engineering, and education in the 21^{st} century:

- The NSF Advisory Committee for Cyberinfrastructure (ACCI) reviews cyberinfrastructure activities and programs across all of NSF, interacts with NSF's directorate advisory committees, and provides advice and strategic feedback on NSF's existing efforts and plans.
- The Cyberinfrastructure Coordination and Leadership Group (CLG) coordinates and manages a set of activities within the broader NSF cyberinfrastructure investment portfolio, including CIF21 programs. This coordination and management includes developing solicitation guidance for common CIF21 programs, coordinating common CIF21 activities, and developing and maintaining an investment roadmap. Directorate CLG membership is designated by the corresponding member of the CIF21 Council (described below).
- The CIF21 Council of NSF assistant directors and office heads provides oversight and advice on strategic directions and programmatic scope for CIF21.
- The Advanced Cyberinfrastructure (ACI) division in the Computer and Information Science and Engineering (CISE) directorate provides leadership for CIF21 activities, engaging with the CIF21 Council in setting NSF-wide strategic directions. This leadership includes developing coordinated CIF21 programs and solicitations, and identifying common approaches and an overall cyberinfrastructure framework.
- As part of CIF21, the other CISE divisions and NSF directorates have working groups that focus on foundational science and engineering, as well as on domain applications. This focus leverages cutting-edge cyberinfrastructure, and also advances critical techniques and technologies to address challenges in computational science and engineering, data management and analytics, and sustained software systems. For example, the Social, Behavioral, and Economic Sciences (SBE) directorate has a working group focused on development of user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental SBE research. A Geosciences (GEO) directorate working group oversees EarthCube, a community-driven data and knowledge environment for the geosciences. A long-standing working group in the Mathematical and Physical Sciences (MPS)

directorate, with regular participation from other directorates including Engineering (ENG) and CISE, coordinates the Computational and Data-enabled Science and Engineering (CDS&E) program.

Scope:
To guide the development of CIF21, the ACCI produced a set of six reports and recommendations for cyberinfrastructure in 2011.[1] These reports and recommendations have been critical in identifying new approaches and capabilities required to advance data,[2] computing infrastructure, software,[3] and workforce development for CIF21. In 2012, the Big Data Research and Development Initiative[4] was highlighted in CIF21, focusing research and development on new capabilities for data-intensive and data-enabled science. The Advanced Computing Infrastructure Strategic Plan,[5] published in 2012, focused on NSF's leadership in creating and deploying a comprehensive portfolio of advanced computing infrastructure to accelerate the pace of discovery in all fields. Along with ongoing focused workshops and events, these reports and initiatives help to define and prioritize programs and activities within the CIF21 framework.

Investment Framework

CIF21 Funding by Directorate
(Dollars in Millions)

Directorate/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$3.75	$8.39	$8.39
Computer and Information Science and Engineering	88.34	84.21	50.00
Education and Human Resources	2.50	2.50	2.50
Engineering	10.00	8.00	4.00
Geosciences	10.99	11.00	12.21
Mathematical and Physical Sciences	34.89	11.50	16.15
Social, Behavioral, and Economic Sciences	6.57	6.82	6.82
Total	**$157.04**	**$132.42**	**$100.07**

Totals may not add due to rounding.

FY 2015 – FY 2016
Following the increased emphasis on domain-specific data-intensive applications, the Critical Techniques and Technologies for Advancing Foundations and Applications of Big Data Science & Engineering (BIGDATA) solicitation was expanded in FY 2015 to address issues of scope and scale. Reproducibility of results is an issue across the sciences, and in FY 2015 NSF held a *Director's Symposium on Robust and Reliable Science: The Path Forward*. In spring 2015, NSF announced the Big Data Regional Innovation Hubs (BD Hubs) program, which aims to augment ongoing activities and ignite new Big Data public-private partnerships through the establishment of four regional BD Hubs. In FY 2015, ENG and the Air Force Office of Scientific Research issued a DCL to support innovative research in the area of Dynamic Data Systems (DDS). This DCL resulted in EArly-concept Grants for Exploratory Research (EAGER) with the potential to transform the ability to understand, manage and control the operation of complex, multi-entity natural or engineered systems, through innovative approaches that consider new dimensions in big data, big computing, and a symbiotic combination of data and computing.

[1] NSF Advisory Committee for Cyberinfrastructure www.nsf.gov/cise/aci/taskforces/index.jsp
[2] A Vision and Strategy for Data in Science, Engineering and Education: www.nsf.gov/cise/aci/cif21/DataVision2012.pdf
[3] Software for Science and Engineering; www.nsf.gov/cise/aci/taskforces/index.jsp
[4] Administration Big Data Initiative: www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_press_release_final_2.pdf
[5] Cyberinfrastructure for 21st Century Science and Engineering: Advanced Computing Infrastructure Vision and Strategic Plan

In FY 2016, foundational research efforts via the BIGDATA solicitation are being broadened to address not only scalability and exploration of new data science capabilities, but also new approaches at the interface between data science and long-term data management and data interoperability for data life cycles that serve multiple stakeholders. In addition, the solicitation will support efforts to employ novel data science methodologies to significantly advance the field's knowledge base on STEM learning and learning environments, broadening participation in STEM, and increasing retention for students traditionally underserved in STEM at the K-12, undergraduate, and graduate levels. The four regional BD Hubs will come online in FY 2016. Each BD Hub will establish a governance structure for its consortium of public and private members, and the BD Hubs collectively will begin developing approaches to ensure cross-hub collaboration and sustainability over the long term. In addition, NSF will begin supporting the next phase of the BD Hubs program by funding a set of BD Spokes that will build out various sectors of particular interest to each BD Hub (e.g., transportation, energy, public safety, and education) to advance Big Data innovation throughout the Nation.

In FY 2015, the Data Infrastructure Building Blocks (DIBBs) program continued to focus on collaboration among all directorates and the formulation of discipline-specific data science and data management pilots. DIBBs increased its scale and scope, emphasizing the value of sharing data beyond a specific institution to the wider science, engineering, and education communities through the Campus Cyberinfrastructure – Data, Networking and Innovation (CC*DNI) program solicitation. As a result of this solicitation, NSF made investments in multi-campus and/or multi-institutional regional cyberinfrastructure to leverage high-performance network paths among campuses, enabling integration of new data-focused services, capabilities, and resources to advance scientific discoveries, collaborations, and innovations.

In FY 2016, the DIBBs program is building on existing community development activities in and across NSF's directorates and offices as well as the previous three years of experiences in the program. NSF directorates are expanding the scale and scope of directorate and multi-directorate Data Science Pilots, building on pilots initiated in previous years and in coordination with the evolving directorate Data Management Plans that are being guided by the *NSF Public Access Plan* (NSF 15-52). Based on individual directorates' investment priorities, expanded scope includes expansion of data analytic algorithms and tools aligned with research priorities, as well as evolution of data management, including the associated social and technical infrastructure. It is anticipated that the program will support activities related to data reproducibility; interoperability of research data as well as specific non-research data; data sustainability plans particularly for high-value community datasets; institutional data policies and community governance; security, privacy, integrity and trustworthiness of research data; exploration of innovative economic/operating models for archiving and curation of research data; and learning and workforce development. The program will pursue increased scale toward national-level, international, and multi-agency activities.

The CDS&E program, led by MPS, ENG, and CISE, includes efforts and approaches for simulation and modeling, along with a specific focus on scaling. The BIO and GEO directorates also participate informally in the proposal and review process. In FY 2015, additional prototype and proof-of-concept approaches for CDS&E were developed. Based on the results of continuing portfolio analysis, the program was structured to address emerging issues of scope and scale. In FY 2016, CDS&E efforts are addressing issues associated with expanding both the base of researchers as well as the participation of new domains and disciplines. In addition, the availability of new tools and technologies resulting from research and infrastructure advances in computation and data are providing new opportunities for communities that have had limited access and use of research data and advanced computing infrastructure.

The Advances in Biological Infrastructure (ABI) program represents NSF's support for cyberinfrastructure for the biological sciences community. While this investment has not previously been highlighted specifically, investments in this area have always been a component of CIF21. In FY 2015, the ABI program supported mid-scale cyberinfrastructure and community coordination activities, such as Research Coordination Networks (RCNs), workshops, and other engagement mechanisms. In FY 2016, ABI is investing in cyberinfrastructure resources that have the potential to advance or transform research in biology supported by BIO. A primary focus is crosscutting, high-priority areas, such as UtB and Genotype to Phenotype.

In FY 2015, EarthCube continued to support community coordination activities, such as RCNs, workshops, and other engagement mechanisms. These activities broadened the base of users as well as the breadth of science conducted via EarthCube. The Integrative Activities track of the EarthCube solicitation supported integration of resources and expansion of cyberinfrastructure to serve other geoscience domains. Early efforts included the development of common approaches and standards including some level of integration and coordination across projects. An EarthCube All-Hands meeting provided a venue for demonstrations of integrative technologies and plans for integrating or employing those technologies in the subsequent few years.

In FY 2016, EarthCube is continuing to support community coordination activities and the development of common approaches. Based on the results from the governance and cyberinfrastructure communities, EarthCube is developing programs that begin to bridge and support multiple geoscience communities. This includes integrating existing pilots and prototypes to address issues of scale and research support. In addition, EarthCube is focusing on at-scale issues including development and deployment of common approaches and structures. This includes development of common tools, data systems, and virtual organizations to support the emerging geoscience communities and to coordinate regional and national cyberinfrastructure facilities.

In FY 2015, the Software Infrastructure for Sustained Innovation (SI^2) program began working more closely with the DIBBs program to encourage proposals that have both software and data elements. SI^2 also developed a supplement mechanism through which NSF awardees could apply for additional funds to support creating and supporting open source software developed through general (non-SI^2) projects. These supplements were co-funded by the SI^2 program and the funders of the original award. This mechanism replaced much of the existing software reuse activity funded as part of CIF21. Additionally, the SI^2 program held a PI meeting for grantees in FY 2015. In FY 2016, the SI^2 program is expanding the scope of its award portfolio by introducing the first Software Infrastructure for Sustained Innovation (S2I2) awards. As it continues to develop software sustainability models for scientific software, it is also beginning to focus on common approaches and issues across multiple institutions and software projects, including integration and coordination of development and deployment as well as validation and verification. This includes a focus on software architecture and infrastructure for major NSF scientific and engineering priorities and investments including possible international joint funding activities.

The NSF Research Traineeship (NRT) program is designed to encourage the development of new, potentially transformative, and scalable models for STEM graduate training that ensure graduate students develop the skills, knowledge, and competencies needed to pursue a range of STEM careers. In FY 2015, NRT supported the priority theme Data-Enabled Science and Engineering (DESE). DESE is aligned directly with CIF21, and includes an emphasis on computational- and data-enabled science and engineering. NRT will continue to support the CIF21/DESE theme in FY 2016.

In FY 2015, a revised and updated version of the Building Community and Capacity in Data Intensive Research in Education (BCC-EHR) solicitation was issued, along with a new solicitation, Resource Implementations for Data Intensive Research in the Social, Behavioral, and Economic Sciences (RIDIR). RIDIR is designed to enable user-friendly, large-scale, next-generation data resources and relevant analytic techniques to advance fundamental research in SBE areas of study. RIDIR awards are constructing databases and/or relevant analytic techniques, and will ultimately produce finished products to enable new types of data-intensive research in multiple disciplines or fields. The databases/techniques will have significant impacts across multiple fields by enabling new types of data-intensive research that includes, but is not necessarily limited to, the social, behavioral, and economic sciences. In FY 2016, NSF will issue a revised and updated version of the BCC-EHR solicitation and will continue to support development of user-friendly, large-scale, next-generation data resources and relevant analytical techniques to advance fundamental social, behavioral, and economic sciences research through increased investment in the RIDIR program.

FY 2017 Request

- Big Data-related activities supported under CIF21 will begin transitioning to new activities within D4SDA in FY 2017. NSF will continue to build out various sectors of particular interest to each BD Hub to advance sector innovation in each region.
- NSF support for data infrastructure for research and education through the DIBBs program will begin transitioning to the D4SDA investment area in FY 2017. This support will build upon foundational data and computational science advances guided by research and education priorities within and across directorates. This support will also be informed by NSF's evolving policies for data management, data citation, and public access. Individual research community considerations of accessibility, reproducibility, efficient sustainability, policy, confidentiality, and privacy, in addition to a range of scalability needs, will result in a mature, extensible, flexible data ecosystem tailored to the Nation's research priorities.
- CDS&E will continue to enable researchers to address the most challenging scientific problems of our time. It will help to create computational resources and a sustainable career path for computational and data scientists so that they become a permanent part of the scientific workforce. Support for CDS&E will continue beyond the end of the CIF21 activity.
- ABI will continue to support midscale investments that advance data, software, and collaborative infrastructure in support of several priority research investments including Understanding the Brain, Genotype to Phenotype, and Plant Genome.
- EarthCube will produce an integrated framework of cyberinfrastructure for the open and easy discovery and access of geoscience data, software and services, information, and computational resources. It will also facilitate the coordination of geoscience data and software facilities to better serve the science requirements of the entire research community. The academic geosciences community will gain a stable venue to coordinate future infrastructure advances as science drivers and technologies change. Additionally, EarthCube will enable new transformative geosciences research and education, through improved ability to access and analyze geosciences data, using effective software, models, and analytical tools that can simulate and examine complex and interrelated Earth processes. Support for EarthCube will continue beyond the end of the CIF21 activity.
- SI^2 will lead to an increase in shared software for use across many scientific fields. It will also increase the incentive to develop such shared software without direct NSF support, which will make the concept of shared software as infrastructure sustainable, and this will result in increased and improved science and engineering research. SI^2 projects will continue to develop software for use by broad communities, with specific metrics based on the sizes of the user communities and their science and engineering research productivity. These metrics support the goal of creating long-term, sustainable impact. Funding for SI^2 will begin to transition to new activities under NSCI in FY 2017, focusing on scientific software architecture and infrastructure for new approaches to computational and data-enabled discovery.
- Prior investments in the NRT CIF21/DESE priority theme will continue to support graduate students in computational- and data-enabled science and engineering, and lead to the development and testing of potentially transformative and scalable models for graduate education more broadly.
- In FY 2017, EHR will fund research addressing the following issues:

- Employing data science methodologies to significantly advance the field's knowledge base on STEM learning and learning environments, broadening participation in STEM, and increasing retention for students traditionally underserved in STEM at the K-12, undergraduate and/or graduate levels; and
- Advancing, adapting and developing novel data science methods and techniques that are distinctly suited to answering educational research questions.
- The projects funded through the RIDIR solicitation are expected by FY 2017 to lead toward: (1) new large-scale databases, substantial expansion or revision of extant databases, and/or the merging of extant databases that will enable data-intensive SBE research (such as research involving data resources that are well beyond the storage requirements, computational intensiveness or complexity that is currently typical in SBE areas of research); and/or (2) analytic tool(s) that would serve to enhance database use to address significant SBE research questions. RIDIR will enhance the ability to conduct data-intensive research that will address broad, important, fundamental SBE research questions.

FY 2018

While CIF21 ends in FY 2017, the deep integration of cyberinfrastructure with research will continue to transform the discovery process across all disciplines. NSF will develop a subsequent, focused set of activities as part of NSCI. In response to multiple technological transitions, the above-mentioned data themes, and the intimate role that computation plays in research leadership, NSF will continue to focus efforts on advancing the Nation’s computational infrastructure for research. In addition, through the new D4SDA investments, NSF will support research and research infrastructure for advancing data science, data management, and data policy.

Evaluation Framework

NSF has deployed a variety of tools to evaluate the scientific and educational impact and progress of the various CIF21 programs. The progress of the implementation of CIF21 was monitored and reviewed quarterly as part of an agency performance goal in FY 2014 and FY 2015. For more information about monitoring key program investments, see the FY 2015 Annual Performance Report in the Performance chapter.

INNOVATIONS AT THE NEXUS OF FOOD, ENERGY, AND WATER SYSTEMS (INFEWS) $62,180,000 +13,500,000 / 27.7%

Overview

Growth of the global and U.S. population has placed an ever-increasing stress on three key and interconnected resources: food, energy, and water. There is a compelling and urgent need to understand, model, design, and manage the interconnected food-energy-water (FEW) systems, which incorporate natural, social, and human-built components. NSF can make important contributions by building the fundamental knowledge base; developing new ways to integrate heterogeneous data; analyzing, modeling, synthesizing, and controlling complex natural systems; expanding the workforce and piloting engineered solutions.

Of particular and timely interest are the production, resilience, safety, and security of FEW resources, and the systems in place to facilitate their generation, distribution, and consumption. Efficiency and conservation will be important goals to attain as stress on FEW systems increases from population and economic growth, changes in land use practices, and more frequent and large spatial and temporal variations in precipitation, temperatures, and key environmental variables tied to environmental change. Developing countries are under extreme pressure as they endeavor to manage the multiple stressors of poverty, resource competition, agricultural disease, and rising food costs. There are important security implications of increasing stress on these interconnected FEW systems.[1] Recent droughts in California and corresponding impacts on the water, agricultural (food), and energy sectors are timely examples that illustrate these concerns.

The interconnected FEW systems interact in several ways. Water is required for energy-related processes such as hydropower, cooling of electric power plants, and fuel production. Energy is needed for wastewater treatment, desalination, pumping groundwater, and for transport of water and foodstuffs. Water and energy are critical for agriculture and food production. Biofuel production consumes water and, in some instances, can result in food shortages. In addition, different land use practices, increased urbanization, and weather variability have major impacts on water, energy, and agriculture resources. These multifaceted interactions are impacted, on the one hand, by fundamental laws governing various physical, chemical, and biological processes and, on the other hand, by social, behavioral, and economic contexts and decisions made by individuals, organizations, and institutions.

Total Funding for INFEWS
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
-	**$48.68**	**$62.18**

Goals

NSF's investment in INFEWS will:

1. Significantly advance our understanding of the FEW system through quantitative and computational modeling, including support for relevant cyberinfrastructure;
2. Develop real-time, cyber-enabled interfaces that improve understanding of the behavior of FEW systems and increase decision support capability;

[1] Quadrennial Defense Review 2014 (http://www.defense.gov/Portals/1/Documents/pubs/2014_Quadrennial_Defense_Review.pdf)

3. Enable research that will lead to innovative system and technological solutions to critical FEW problems; and
4. Grow the scientific workforce capable of studying and managing the FEW system through education and other professional development opportunities.

Approach

NSF is currently heavily invested in discovery research at a disciplinary level, as well as cross-cutting programs such as Water, Sustainability and Climate (WSC); Sustainable Chemistry, Engineering and Materials (SusChEM); Cyber-Innovation for Sustainability Science and Engineering (CyberSEES); Hazards and Disasters (Hazards SEES); Basic Research to Enable Agricultural Development (BREAD); Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP); and the Dynamics of Coupled Natural and Human Systems (CNH). INFEWS offers a significant opportunity for NSF to build on these investments in order to create new and effective research programs to advance the FEW systems knowledge base. NSF has initiated, and proposes to continue, the following leadership and governance structure for INFEWS:

- A senior leadership committee composed of assistant directors/office heads to provide long-term planning and overall guidance;
- Working groups of division directors and program officers, each overseen by their respective assistant directors/office heads/division directors who are most relevant to the specific activity, to manage programs or activities and to coordinate among activities; and
- Interagency working groups to coordinate interagency activities and joint solicitations, as well as arrangements for engagement and collaboration with international partners.

An interdisciplinary research effort on the interconnected FEW systems, including safety and security of these systems, presents a unique opportunity for NSF to work, within both a national and an international context, toward building a platform for more accurate, process-based models that incorporate relevant social, political, economic, and cultural factors, and enabling innovative solutions to address these critical challenges.

NSF will build on ongoing internal partnerships among participating directorates to engage in collaborative multi-year activities involving two (or more) directorates. Management agreements will define directorate-planned contributions, remaining flexible on the requirement for participation. This flexibility will allow for partnerships with other agencies and international entities. NSF's approach and planned activities will be coordinated with other agencies through the National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability (CENRS).

Investment Framework

INFEWS Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	-	$7.50	$10.00
CISE	-	9.00	6.00
EHR	-	4.00	6.00
ENG	-	10.00	13.00
GEO	-	5.00	10.00
MPS	-	2.40	6.40
OISE	-	1.28	1.28
SBE	-	4.50	4.50
IA	-	5.00	5.00
Total, INFEWS	**-**	**$48.68**	**$62.18**

Totals may not add due to rounding.

FY 2015 – FY 2016

INFEWS represents a natural segue from many NSF programs, including those under the Science, Engineering, and Education for Sustainability (SEES) investment area. As such, INFEWS planning and development activities began in FY 2014 and continued throughout FY 2015. NSF senior management planned for the new investment area as community interest grew and was expressed in workshops and reports in a variety of disciplines. NSF senior management discussions with other federal agencies about common research interests and professional workforce needs were initiated and continue. In FY 2015, NSF supported 17 regional workshops to promote interdisciplinary collaborative approaches to FEW challenges and issued two Dear Colleague Letters (DCLs).[2] Workshops included scientists from Department of Energy (DOE), U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and other agencies and helped inform DCLs.

In FY 2016, NSF announced a multi-directorate INFEWS solicitation[3] to support integrated research towards advancing the goals of the INFEWS investment. The USDA National Institute of Food and Agriculture (NIFA) helped develop the general solicitation and is committing funds to awards relevant to their mission.

The Directorates for Engineering (ENG) and Mathematical and Physical Sciences (MPS) announced a DCL (NSF 15-108) to support research activities in nitrogen, phosphorus, and water in the context of INFEWS in FY 2016. The goal is to advance knowledge of the nitrogen and phosphorus cycles; the production and use of fertilizers for food production; and the detection, separation, and reclamation/recycling of nitrogen- and phosphorus-containing species in and from complex aqueous environments. In FY 2016, the Directorate for Biological Sciences (BIO) plans to release a joint DCL with USDA/NIFA on breakthrough technologies for plant and animal phenotyping and microbiomes. Advanced phenotyping and microbiome technologies will enhance our fundamental understanding of these systems, which will potentially translate into improving agricultural productivity and efficient use of natural resources such as land, water, nitrogen, and phosphorous.

[2] www.nsf.gov/pubs/2015/nsf15108/nsf15108.jsp?amp%3BWT.mc_ev=click;
www.nsf.gov/pubs/2015/nsf15040/nsf15040.jsp

[3] www.nsf.gov/pubs/2016/nsf16524/nsf16524.htm?WT.mc_id=USNSF_27&WT.mc_ev=click

In FY 2016, INFEWS is also one of the priority research theme areas for the NSF Research Traineeship (NRT) program, as part of an effort to create innovative graduate education efforts in areas of national need.

FY 2017 Request

In FY 2017, NSF will continue to support INFEWS research activities. These activities will focus on how FEW systems are embedded in social, political, economic, and cultural contexts; innovation in the safety and protection of food, energy, and water resources, and the systems in place to facilitate their generation, distribution, and/or consumption; computational capacity and cyberinfrastructure needs for analysis of large-scale data, including modeling and simulation; and integration of research with education and training of the next generation workforce.

In FY 2017, BIO plans to issue a solicitation focused on phytobiomes, the microbiomes of plants and surrounding soils and environment, which impact the health and productivity of plants and plant ecosystems. Also, the FEW theme may be emphasized in NSF-wide programs, such as Experimental Program to Stimulate Competitive Research (EPSCoR), Research Experiences for Undergraduates (REU), Dynamics of Coupled Natural and Human Systems (CNH), Macrosystems Biology, and those related to data science (e.g., BIGDATA and Data Infrastructure Building Blocks (DIBBs)).

FY 2018 – FY 2021

In FY 2018 – 2021, NSF will continue to support INFEWS research activities. NSF will enhance interagency and international partnerships and foster cross-disciplinary knowledge-sharing and networking through awards, meetings, workshops, and other activities.

Evaluation Framework

The progress of the implementation of this investment will be monitored and reviewed quarterly to ensure that it is on track as part of a FY 2017 performance goal. For more information about monitoring key program investments, see the FY 2017 Annual Performance Plan in the Performance chapter. All specific investments under INFEWS will be subject to rigorous peer review using NSF's merit review processes, and under the review of cross-NSF teams from staff level to program and division director-level to an agency senior management steering committee. NSF will use lessons learned from large, cross-NSF investment areas (e.g., SEES, I-Corps™) to inform evaluation planning and design for INFEWS. Evaluation activities include:

- Consulting internally and externally regarding evaluation strategy and methodology;
- Characterizing the initial portfolio, using new NSF portfolio management tools;
- Developing evaluation research questions;
- Analyzing NSF project reports for indications of advancement/growth of research; and
- Collecting and analyzing workforce development metrics.

Planning for evaluation has been initiated. Contract support will be engaged as soon as practicable to ensure objectivity of evaluation design and implementation, and the collection of relevant baseline data.

NSF INNOVATION CORPS (NSF I-CORPS™) $30,000,000

+$0 / 0.0%

Overview

Over the last few decades, NSF has been vigorously seeking to strengthen the national innovation ecosystem that builds upon fundamental science and engineering research to feed the development of technologies, products, and processes that benefit society. In FY 2011, NSF established the Innovation Corps (I-Corps™) program to meet such a purpose. I-Corps™ connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, fostering a national innovation ecosystem that links scientific discovery with technology development, societal needs, and economic opportunities. The I-Corps™ program provides immersive, experiential entrepreneurial education to scientists and engineers by supporting I-Corps™ Teams and building a National Innovation Network (NIN) through I-Corps™ Nodes that are designed to provide learning environments for the I-Corps™ Teams. The I-Corps™ Nodes also support regional needs for innovation education, infrastructure, and research. NSF has also awarded multiple I-Corps™ Sites, which help those institutions with existing entrepreneurial activities to spawn additional Teams.

Total Funding for I-Corps™

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$26.19	$30.00	$30.00

Goals

The goals of the I-Corps™ program are to:

- Capitalize on NSF's investment in fundamental research;
- Offer academic researchers an opportunity to learn firsthand about technological innovation and entrepreneurship, and thereby fulfill the promise of their discoveries; and
- Prepare students for real-world experience through curricular enhancements, and provide them with opportunities to learn about and participate in the process of transforming scientific and engineering discoveries to meet societal needs.

Approach

The I-Corps™ program has three components: I-Corps™ Teams, Nodes, and Sites.

The I-Corps™ Team awards support NSF-funded researchers who, in Teams (an I-Corps™ Team includes the principal investigator, the entrepreneurial lead, and the I-Corps™ mentor), are interested in transitioning their research out of the lab. The Teams are selected based on the maturity of the effort (i.e., if the research is ready to leave the lab), strength of the team, and anticipated market value. The I-Corps™ Teams are given access to immersive experiential entrepreneurial education and additional support, in the form of mentoring and funding, to help determine the readiness to commercialize technology resulting from NSF-funded projects. Upon completion of the I-Corps™ curriculum, the Teams are expected to demonstrate: 1) a clear go/no-go decision regarding viability of products and services; 2) should the decision be to move the effort forward, a transition plan to do so; and 3) a technology demonstration for potential partners. As of June 2015, 534 Teams have completed the curriculum. Approximately 45 percent of these Teams have started their own companies, and two of these companies have been acquired. Many of these companies have also received Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) funds from various federal agencies, as well as investments from the private sector.

I-Corps™ Nodes and Sites aim to further build, utilize, and sustain a national innovation ecosystem that augments the development of technologies, products, and processes that benefit the Nation. The Nodes provide training to I-Corps™ Teams; establish regional activities to cultivate the growth of innovation ecosystems; develop tools and resources that benefit the entire I-Corps™ program within a two- to three-year timeframe; and identify and pursue longer-term (five-plus years) research and development projects. I-Corps™ Sites are funded at academic institutions that have existing innovation or entrepreneurial units, to enable and support teams to transition their ideas and technologies into the marketplace.

NSF also established the National Innovation Network (NIN) that brings together the I-Corps™ community, including Node principal investigators (PIs), faculty from all Nodes, and representatives of Sites, for open sharing and learning to help improve outcomes for I-Corps™ Teams and further develop the I-Corps™ community.

NSF's Innovation Corps for Learning (I-Corps™ L) was established within the Directorate for Education and Human Resources (EHR) in FY 2013 to promote opportunities for widespread adoption, adaptation, and utilization of discoveries and promising practices stemming from education research and development. I-Corps™ L challenges NSF researchers to think beyond their research results and toward broader adoption of Science, Technology, Engineering, and Mathematics (STEM) education and learning innovations. I-Corps™ L supports the National Science and Technology Council (NSTC) strategic plan calling for broader implementation of effective instructional practices and advances in education.

The I-Corps™ program is managed within NSF by a core group of program officers comprising representatives from all directorates. The lead program officer is from the Directorate for Engineering. In addition to working closely with all subject matter experts within the directorates, the lead program officer and the I-Corps™ core group regularly meet with other federal agency representatives who have expressed interest in implementing similar programs within their own agencies. To date, NSF has signed Memoranda of Understanding (MOU) with the Advanced Research Projects Agency-Energy (ARPA-E), National Institutes of Health (NIH), Department of Energy/Office of Energy Efficiency and Renewable Energy (DOE/EERE), Department of Homeland Security (DHS), National Security Agency (NSA), Department of Defense (DOD), and Small Business Administration (SBA). In addition, NSF has signed an MOU with the Chancellor of the Ohio Board of Regents and the Bill & Melinda Gates Foundation.

Investment Framework

I-Corps™ Funding by Directorate

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	$0.85	$1.00	$1.00
CISE	11.02	11.65	11.65
EHR	0.55	1.55	1.55
ENG	11.05	13.00	13.00
GEO	0.92	0.60	0.60
MPS	1.30	1.70	1.70
SBE	0.50	0.50	0.50
TOTAL	**$26.19**	**$30.00**	**$30.00**

FY 2015 – FY 2016

The I-Corps™ program is a key element in a series of NSF-supported programs concentrating on the innovation ecosystem. NSF has a number of long-standing programs that support the innovation ecosystem, such as Engineering Research Centers (ERC), Industry/University Cooperative Research Centers (I/UCRC), Partnerships for Innovation (PFI), Science and Technology Centers (STC), Grant Opportunities for Academic Liaison with Industry (GOALI), Centers for Chemical Innovation (CCI), and Materials Research Science and Engineering Centers (MRSEC).

In FY 2015, the I-Corps™ program supported 210 NSF Teams at $50,000 each, for up to six months. In FY 2016, about 220 NSF Teams are anticipated. Additionally, NSF has collaborated with multiple federal agencies to expand the I-Corps™ program and its impact. NSF and ARPA-E signed a MOU in FY 2013 for collaboration that is planned to continue through FY 2018. ARPA-E has so far funded eight Teams to go through the I-Corps program. In FY 2014, the NIH and NSF announced a collaboration to offer an I-Corps™ curriculum geared towards the life sciences for NIH SBIR grantees in FY 2015. The partnership is planned to continue through June 2017, and NIH has so far funded 19 Teams to go through the I-Corps™ program. NSF also signed an MOU with the Department of Homeland Security (DHS), and DHS has so far funded three Teams. The MOU with DHS has expired, but discussions are continuing. Additional MOUs that will be in place through at least FY 2017 include SBA, DOD, the U.S. Department of Agriculture, and the Gates Foundation.

Today, a hypothesis-driven approach to evaluating technical and market viability is offered to all I-Corps™ Teams through I-Corps™ Nodes. In both FY 2011 and 2012, two I-Corps™ Nodes were awarded. In FY 2013, NSF awarded three more Nodes. In FY 2014, NSF awarded two additional Nodes, bringing the total number of I-Corps™ Nodes to seven. In FY 2015, two of the seven Nodes were extended thus maintaining the total number of Nodes at seven. In FY 2016, NSF will fund between five and seven new Nodes or renewals of existing Nodes to bring the total number of active Nodes to eight or nine in FY 2016.

NSF also established the I-Corps™ Sites at academic institutions that already have existing innovation or entrepreneurial units, enabling them to nurture students and/or faculty who are engaged in science and engineering research projects with the potential for transition to the marketplace. The Site award size is up to $100,000 per year for three years. In FY 2013, four I-Corps™ Sites were funded. In FY 2014, NSF awarded 11 additional Sites. In FY 2015, NSF awarded 21 sites to increase the total number of active Sites to 36. NSF plans to support up to 57 active Sites in total in FY 2016.

The program reaches throughout NSF's entire portfolio, engaging PIs from every directorate previously or currently supported by NSF for their research and education activities. I-Corps™ connects the academic research community with experts in innovation and entrepreneurship, who can help mentor budding entrepreneurs and evaluate the commercial viability of their ideas. Through I-Corps™ Sites and Nodes, the program is tapping into existing entrepreneurial support within many universities and is spawning regional innovation centers. With the portfolio of I-Corps™ Teams, Sites, and Nodes, NSF is helping to build a national innovation ecosystem. Overall, the program has been very well received by student entrepreneurs wishing to start small businesses, has increased faculty awareness of potential connections between fundamental research and innovation that is positively impacting their own research and educational practices, and has raised the level of interest in NSF-supported research from private investors.

FY 2017 Request

Through leveraging existing entrepreneurial and innovation capacities in universities and tapping into federal, state, and regional resources, the I-Corps™ NIN, which is comprised of Nodes and Sites, holds significant potential to reach out to a large number of budding and existing innovators and entrepreneurs.
In FY 2017, NSF will support up to 230 I-Corps™ Teams, including up to 20 I-Corps™ L Teams, and expects to support a portfolio of eight to nine I-Corps™ Nodes and up to 71 active I-Corps™ Sites. NSF also plans to invest approximately $1.0 million on I-Corps™ Evaluation & Assessment activities.

NSF will also continue to build partnerships with stakeholders who have access to innovators and entrepreneurs including federal agencies, state governments, universities, and non-profit organizations. NSF also envisions potential partnerships with states, such as that with Ohio, will lead to further expansion of the I-Corps™ model across the Nation.

FY 2018 – FY 2020

The I-Corps™ program is anticipated to be an integral part of NSF's investment portfolio going forward.

Evaluation Framework

I-Corps™ was one of NSF's three priority goals for FY 2013 - 2014. This priority goal was to increase the number of entrepreneurs emerging from university labs. Progress was monitored quarterly by agency senior management and was reported on the website of Performance.gov. Specifically, the priority goal stated that, by September 30, 2013, 80 percent of I-Corps™ Teams will have tested the commercial viability of their products or services. The I-Corps™ program exceeded that goal.

Regarding longitudinal monitoring of the outcomes achieved by the Teams, a logic model was developed and a data collection system to elicit quantifiable measures of both short-term outputs and outcomes and long-term outcomes was put in place in 2014. For example, successful completion of an I-Corps™ Team grant would be expected to contribute to one or more of the following:

- New start-ups;
- New licensing activities;
- SBIR/STTR proposals and awards;
- A business plan suitable for review by private investors;
- Students prepared to be entrepreneurially competitive; and
- New curriculum development or improvement focusing on entrepreneurship and innovation.

In FY 2014, NSF's Evaluation and Assessment Capability section in the Office of Integrative Activities commissioned a study of the feasibility of conducting a rigorous impact evaluation of I-Corps™ Teams. The feasibility study concluded that an evaluation of the I-Corps™ Teams program is feasible. Most of the elements needed for a summative or impact evaluation are available or there is a plan for collecting them on an ongoing basis.

Based on the feasibility study, NSF initiated a request for proposals to identify a contractor to perform a rigorous evaluation of the I-Corps™ Teams. A contractor was selected and engaged in FY 2015. The assessment is planned for completion in the summer of 2017. The evaluation will assess:

- The culture of innovation cultivated by the program;
- Entrepreneurial knowledge among academics;
- Commercialization outcomes attributable to the I-Corps™ intervention; and
- Other spillover effects of the Teams program.

RISK AND RESILIENCE $43,150,000

+$2,000,000/ 4.9%

Overview

The economic competitiveness and societal well-being of the United States depend on the affordability, availability, quality, and reliability of the infrastructure services provided. These infrastructure services include transportation (road, rail, sea, and air), energy (electricity, gas, oil, and renewable), water, communications and networks (wireless and wired, including the internet), banking and finance, critical manufacturing, food and agriculture, healthcare, and many other components. The increased penetration and use of modern technologies has improved our Nation's productivity and quality of life. These technologies have become deeply embedded into the functioning and the expectations of society, and reliance upon technological infrastructure is truly unprecedented.

Our increasing dependence on infrastructure services has increased the impact of risks that may cause these systems to fail. Risk severity can be understood as the product of the probability of an event and the magnitude of the event's consequences. These risks arise from at least two distinct sources: (a) extreme natural events such as tornadoes, space weather, hurricanes, storms, and earthquakes, and (b) human-induced events such as malicious attacks and mechanical and technological failures. Some predict that extreme weather events and civil unrest will increase in frequency and severity.

It is essential that we work toward improving predictability and risk assessment and increasing resilience in order to reduce the impact of extreme events on our life, society, and economy. NSF is uniquely positioned to support such improvements that require multidisciplinary expertise in science, engineering, and education. NSF is focused on fundamental science and engineering issues such as understanding the dynamic processes that produce extreme events, how people respond to extreme events, and how to engineer resilient infrastructure. The enhanced scientific and engineering knowledge base in these areas will lead to better prediction, improved warning systems, and reduced disruption that will support the missions of other agencies such as the National Oceanic and Atmospheric Administration (NOAA), the Department of Homeland Security (DHS), and the U.S. Geological Survey (USGS). Accordingly, this initiative is seen as complementary, rather than duplicative, to the interests of other agencies. Partnerships with mission agencies are critical to NSF's ability to meet its goal of enabling research results that can be translated into applications that provide societal benefits.

Total Funding for Risk and Resilience

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$19.34	**$41.15**	**$43.15**

Goals

NSF's goals through this investment are to:

(1) Advance knowledge of risk assessment and predictability through support for improvements in our ability to understand, model, and predict extreme events and natural hazards; and.

(2) Support the creation of tools and technologies for increased resilience, including novel engineered systems solutions for resilient infrastructures, particularly those that leverage the growing infusion of cyber-physical-social components into the infrastructures.

Approach

NSF plans to use the following leadership and governance structure for the Risk and Resilience investment:

- A senior leadership committee composed of assistant directors/office heads to provide long-term strategy and overall guidance;
- Working groups comprised of program officers and division directors, each overseen by assistant directors/office heads who are most relevant to the specific activity, to coordinate programs or activities; and
- Interagency working groups to coordinate interagency activities, as well as arrangements for engagement and collaboration with international partners if needed.

NSF supports basic research in the scientific and engineering disciplines necessary to understand disasters and extreme natural events. A coordinated, interdisciplinary investment in this arena would result in a comprehensive and integrated risk and resilience knowledge base useful for informed decision-making and risk mitigation. An interdisciplinary research effort on risk and resilience systems presents a unique opportunity for NSF to work, within both a national and an international context, toward building a platform for more accurate models and improved predictive capabilities that incorporate relevant social, political, economic, and cultural factors. International partners have considerable expertise and information to offer U.S. researchers in mutually synergistic ways. For example, the NSF Directorate for Computer and Information Science and Engineering (CISE) joint program with the Japan Science and Technology Agency (JST) on Big Data for Disaster Research creates synergies between U.S. and Japanese researchers focused on improving the resilience and responsiveness of emerging computer systems and networks. NSF's Directorate for Engineering (ENG) has longstanding international partnerships in earthquake research programs, providing U.S. researchers access to unique earthquake engineering experimental facilities and opportunities for research collaborations. Advances will be accelerated by similar partnerships with other countries.

NSF is taking a two-pronged approach to meet the goals of the Risk and Resilience investment area as described below.

Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP): Our increasing dependence on infrastructure services has increased the impact of risks that may cause these systems to fail. Furthermore, the impact of deterioration of critical infrastructures becomes amplified since these infrastructures depend on each other for their function. For example, the electrical power system depends on the delivery of fuels for generating stations through transportation services, the production of those fuels depends on the use of electrical power, those fuels are needed by the transportation services, and all of these systems are intertwined with human decision-making. The disruption of electrical power impacts water, emergency services, finance, and government services, among others. All of these services in turn depend on communication and control services provided by cyber-physical infrastructure – including computing, networking, data, and control services provided by complex, multi-scale interdependent systems and software – and cannot function without electricity. This complex set of interdependencies between the components of an interconnected set of critical infrastructures presents significant challenges to conceptualize, understand, model, design, and manage interdependent critical infrastructure systems (ICIs).

The CRISP program is designed to: (1) foster an interdisciplinary research community of engineers, computer and computational scientists, and social and behavioral scientists that will create new approaches and engineering solutions for the design and operation of infrastructure processes and services; (2) enhance the understanding and design of ICIs and processes that provide essential goods and services despite disruptions and failures from any cause--natural, technological, or malicious; (3) create the knowledge for innovation in ICIs so that they safely, securely, and effectively expand the range of goods and services they enable; and (4) improve the effectiveness and efficiency with which ICIs deliver existing goods and services.

Prediction of and Resilience against Extreme EVENTS (PREEVENTS): Natural disasters cause thousands of deaths annually, and, in 2013 alone, they caused over $130 billion in damage worldwide.[1] It is estimated that recovery from Hurricane Sandy will cost over $65 billion, and that the drought of 2012 cost the U.S. economy over $30 billion. A focused research effort, PREEVENTS will help us to better understand and mitigate the risks posed to the U.S. by natural hazards. PREEVENTS will deepen fundamental scientific understanding of natural processes underlying geohazards and extreme events, and will enable improved quantitative models and qualitative research that can enhance societal preparedness and resilience against such events. PREEVENTS will focus on natural hazards and extreme events, and will include the potential for disciplinary and multidisciplinary projects at all scales, especially areas ready for significant near- or medium-term advances.

PREEVENTS is the logical successor to the Hazards SEES program, but with a more GEO-focused perspective. PREEVENTS is designed to (1) enhance understanding of the fundamental processes underlying geohazards and extreme events on various spatial and temporal scales, as well as the variability inherent in such hazards and events; (2) improve models of geohazards, extreme events, and their impacts on natural, social, and economic systems; and (3) develop new tools to enhance societal preparedness and resilience against such impacts. PREEVENTS will focus on natural hazards and extreme events, not purely technological or deliberately or accidentally caused events/processes.

Investment Framework

Risk and Resilience Funding by Directorate
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
CISE	$5.50	$6.00	$6.00
ENG	12.00	12.00	14.00
GEO	-	17.75	17.75
MPS	-	0.50	0.50
SBE	1.84	4.90	4.90
Total	**$19.34**	**$41.15**	**$43.15**

Totals may not add due to rounding.

<u>**FY 2014 – FY 2016**</u>

CRISP: In FY 2014, NSF conducted various planning activities including meetings, presentations, and workgroup formation to identify research areas in Risk and Resilience that NSF is uniquely positioned to support. A pilot competition, titled Resilient Interdependent Infrastructure Processes and Systems (RIPS),[2] jointly supported by the ENG, CISE, and Social, Behavioral, and Economic Sciences (SBE) directorates resulted in submission of 81 projects (156 proposals) that covered a wide range of infrastructures and cyber systems, and ten projects were supported.

In FY 2015, building on RIPS, NSF announced a solicitation for the CRISP program[3] jointly supported by ENG, CISE, and SBE. A total of 90 projects (150 proposals) were submitted. New awards totaling approximately $20.0 million were made in FY 2015 to support research in theory and modeling, as well as

[1] Munich Re (2014). Topics Geo. www.munichre.com/site/corporate/get/documents_E1043212252/mr/assetpool.shared/Documents/5_Touch/_Publications/302-08121_en.pdf
[2] www.nsf.gov/pubs/2014/nsf14524/nsf14524.htm
[3] www.nsf.gov/pubs/2015/nsf15531/nsf15531.htm

major new interdependent infrastructure research using empirical data to conceptualize and study ICIs as processes, services and systems.

In FY 2016, building on strong foundations of core science and engineering programs in CISE, ENG, and SBE, NSF issued a new solicitation for the CRISP program[4] that will continue to catalyze collaborations among researchers across the domains of engineering; computer information and computational science; and the social, behavioral, and economic sciences to create theoretical frameworks and multi-disciplinary models of ICIs.

PREEVENTS: In FY 2015, NSF issued a final solicitation under the Interdisciplinary Research in Hazards and Disasters (Hazards Science, Engineering, and Education for Sustainability (SEES)) program[5] and issued a Dear Colleague Letter (DCL)[6] to announce the upcoming PREEVENTS program, describing general program goals. Research supported by the Hazards SEES program laid the groundwork for PREEVENTS.

The DCL issued in FY 2015 solicited proposals for workshops and Research Coordination Networks (RCN) and relevant funding opportunities with existing GEO programs to be supported in FY 2016. PREEVENTS workshops will foster community development in some disciplinary areas; foster cross-disciplinary communities for problems that need such an approach but are not yet well established; and gather information for use in future PREEVENTS solicitations. RCNs will advance program goals by supporting groups of investigators to share information and ideas; coordinate ongoing or planned research activities; foster synthesis and new collaborations; develop community standards; and in other ways advance science and education through communication and sharing of ideas across disciplinary, organizational, geographic, and international boundaries. These activities will inform a solicitation to be issued in FY 2016.

FY 2017 Request

In FY 2017, NSF will continue the CRISP and PREEVENTS research programs, which will advance our scientific and engineering knowledge base and educate the next generation of scientists and engineers for increasing the resilience of our infrastructures in the face of changing and increasing risks.

CRISP: In FY 2017, NSF will continue support for the CRISP program that will deepen fundamental knowledge and stimulate innovations to improve resilience, interoperations, performance, and readiness in ICIs; to understand organizational, social, psychological, spatial, legal, political, and economic obstacles to improving ICIs, and to identify strategies for overcoming these obstacles; and to understand the role of these advances in the context of increasingly smart and connected communities that are dependent upon the successful operation of ICIs.

PREEVENTS: In FY 2017, NSF will continue to support proposals on the fundamental science behind natural hazards and extreme events, including those that are multidisciplinary or require a collaborative team to address the research or technological challenge.

FY 2018 – FY 2020

In FY 2018 – FY 2020, NSF will continue to support the CRISP program and related research activities to advance knowledge and discoveries in critical interdependent infrastructure systems and processes. NSF will also continue to support PREEVENTS-related research to enhance our understanding of risk and resilience knowledge base useful for informed decision-making and risk mitigation.

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[4] www.nsf.gov/pubs/2016/nsf16519/nsf16519.htm
[5] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=504804&ods_key=nsf14581
[6] www.nsf.gov/pubs/2015/nsf15117/nsf15117.jsp

Evaluation Framework
Investments and activities under the Risk and Resilience umbrella will be subject to periodic reviews and assessments. All specific investments will be subject to rigorous peer review using NSF's merit review processes, and under the review of cross-NSF teams, from staff level to program and division director-level to an agency senior management steering committee. As the investment area evolves, decisions will be made regarding changes in emphasis areas, the need to assimilate Risk and Resilience efforts into core programs, and timing for sunsetting of specific investments.

NSF will use lessons learned from large, cross-NSF investment areas (e.g., SEES and NSF Innovation Corps (I-Corps™)) to inform evaluation planning and design for Risk and Resilience. It is anticipated that NSF will have centralized capacity to develop a statement of work for enlisting contractor support.

Evaluation activities include:
- Consulting internally and externally regarding evaluation strategy and methodology;
- Characterizing the initial portfolio, using new NSF portfolio management tools;
- Developing evaluation research questions;
- Analyzing NSF project reports for indications of advancement/growth of research; and
- Collecting and analyzing workforce development metrics.

SCIENCE, ENGINEERING, AND EDUCATION FOR SUSTAINABILITY (SEES) $52,480,000 -$22,250,000/ -29.8%

Overview

A sustainable world is one in which human needs are met equitably without harm to the environment and without sacrificing the ability of future generations to meet their needs. Meeting this formidable challenge requires an increase in understanding of the integrated system of society, the natural world, and the alterations humans bring to Earth. NSF's Science, Engineering, and Education for Sustainability (SEES) activities aim to address this need through support for interdisciplinary research and education activities that cross the boundaries of the physical sciences, natural sciences, engineering, mathematics, computational sciences, human behavior, the social and economic sciences, and educational sciences to develop new understandings, theories, models, and technologies.

Total Funding for SEES

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$183.01	**$74.73**	**$52.48**

Goals

SEES activities span the entire range of scientific domains at NSF and have three overarching multi-year goals:

1) Support interdisciplinary research and education that can facilitate the move towards global sustainability;
2) Build linkages among existing projects and partners and add new participants in the sustainability research enterprise; and
3) Develop a workforce trained in the interdisciplinary scholarship needed to understand and address the complex issues of sustainability.

Approach

SEES is a multi-year effort to coordinate and grow research and education associated with the environment, energy, and sustainability. NSF's work under SEES is a blend of activities − formal solicitations and less formal announcements of interest (e.g., Dear Colleague Letters) − that span multiple scientific disciplines and require input and oversight from multiple NSF directorates. Research on complex environmental pathways is supported and emphasized across NSF and is supplemented by activities focused on sustainable materials and technologies. SEES activities also help to build up the cross-disciplinary workforce for sustainability research and education, and to engage students and the public on sustainability science and engineering and their social implications. NSF conducts this work in awareness of and in concert with other federal agencies and national and international stakeholder groups whose function and mission complement NSF's role to ensure that sustainability goals are carried forward.

SEES programs are rooted in long-term, ongoing, environmental, energy, and education research. The portfolio approach—as opposed to a large single program—facilitates coordination, monitoring, and impact across the major investment areas and also across NSF, as SEES activities are complex and highly interdisciplinary. The SEES organizational structure includes:

- A senior leadership committee composed of assistant directors/office heads to provide overall planning and guidance;
- Cross-agency working groups of program directors, each overseen by assistant directors/office heads/division directors who are most relevant to the specific activity to manage programs or activities; and

- Interagency working groups and international partnerships to carry out transition planning as the initiative sunsets in FY 2017.

Investment Framework

SEES Funding by Directorate

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	$21.00	$17.50	$17.50
CISE	13.32	-	-
ENG	19.39	3.00	3.00
GEO	59.00	34.00	18.50
MPS	50.85	16.00	13.00
SBE	3.00	-	-
OISE	16.45	4.23	0.48
Total	**$183.01**	**$74.73**	**$52.48**

Totals may not add due to rounding.

<u>FY 2010 – FY 2015</u>

NSF established the SEES investment area in FY 2010 in order to use a systems-based approach to understanding, predicting, and reacting to change in the linked natural, social, and built environment and to address challenges in environmental and energy research and education. NSF supported sustainability-related research and education for decades and SEES built on this foundation by bringing programs that address sustainability into a common framework to optimize investments and outcomes. The initial programs in FY 2010 were the Climate Change Education Program, Dimensions of Biodiversity (DoB), Earth Systems Modeling (EaSM), Ocean Acidification (OA), and Water Sustainability and Climate (WSC).

In FY 2011, NSF maintained momentum in the SEES investment area by augmenting existing programs and issuing a Dear Colleague Letter. In FY 2012, NSF expanded SEES through significant investments in four new programs: SEES Fellows; Sustainability Research Networks; Sustainable Energy Pathways; and a SEES-focused Partnerships for International Research and Education (PIRE) competition. In FY 2013, NSF initiated five SEES programs – Coastal SEES, Arctic (ArcSEES), Hazards SEES, Cyber SEES, and Sustainable Chemistry, Engineering and Materials (SusChEM) -- to complement earlier programs and to focus on environmental, technological, and societal resilience; dissemination of results; responsiveness to societal needs; and workforce development.

NSF continued to support and coordinate the many SEES programs throughout FY 2014 and FY 2015. In the case of some multi-year continuing awards, FY 2015 funds were used to support activities in the following fiscal year. SEES competitions in FY 2014-2015 included: DoB, WSC, CyberSEES, Coastal SEES, Dynamics of Coupled Natural and Human Systems (CNH), Hazards and Disasters (Hazards SEES), SusChEM, Arctic SEES, and Food Systems. Of particular note is the Sustainability Research Networks (SRN) solicitation focused on increasing understanding of the complicated landscape of urban sustainability, which has emerged as a critical need for the 21st century.

FY 2016

The FY 2016 estimate for SEES is $74.73 million. FY 2016 funding will support the following SEES programs: DoB, EaSM, SRN, Coastal SEES, Hazards SEES, SusChEM, and PIRE. SEES programs continue to support important scientific and societal contributions during this phase-down period, and to make significant progress towards achieving programmatic goals through existing projects. During FY 2016, NSF continues to stress consolidation and coordination of existing activities in keeping with the sunsetting of the investment area in FY 2017.

FY 2017 Request

While FY 2017 is the last year in which funding will be formally associated with the SEES portfolio, NSF has and will continue to invest in and make progress towards the research necessary for a sustainable human future, via SEES and many other programs and mechanisms. FY 2017 SEES funding will support the DoB, EaSM, SRN, Coastal SEES, and SusChEM programs. NSF senior management is planning for the Hazards and WSC programs to continue beyond 2017. NSF plans to continue support for Hazards-related research projects under NSF's Risk and Resilience investment area. Aspects of the WSC program and food and energy systems sustainability research will be folded into the Innovations at the Nexus of Food, Energy, and Water (INFEWS) investment area. SusChEM is anticipated to transition to an ongoing program among three NSF directorates (MPS, ENG, and GEO). SEES programs with ongoing community interest that will be supported through NSF core programs include: ArcSEES, Coastal SEES, DoB, EaSM, OA, and CNH (SEES track).

Evaluation Framework

Significant thought has gone into how to define success under SEES, and monitoring and evaluation have been aspects of the SEES portfolio since its inception. The progress of the implementation of this investment was monitored and reviewed quarterly as part of a performance goal in FY 2014 and FY 2015. For more information about monitoring key program investments, see the FY 2015 Annual Performance Report in the Performance chapter. Additionally, NSF has received abundant internal and external feedback on the portfolio and its programs through trans-disciplinary workshops, advisory committee meetings, a National Academies conference, and various newsletters, articles, and publications. In FY 2014, NSF issued a Request for Quotes and awarded a contract for evaluation of the SEES portfolio. Evaluation activities under the contract include:

- **Evaluation Design and Plan** − developing research questions and framework for analysis, including logic models, and developing data collection instruments and methodologies for those analyses (final plan delivered December 2014; final evaluation report due December 2017).
- **Historical Review** − understanding of sustainability-related activities over time, how SEES fits into history, and to discern if the coordinated approach under SEES has brought about different outcomes in terms of increased productivity, scientific findings, and interest level (final report delivered July 2015).
- **Comparative Analyses of SEES and non-SEES NSF programs** − to determine if activities conducted and programs developed under the SEES portfolio are achieving different outcomes compared to similar NSF programs, and if the SEES portfolio is filling a gap in the sustainability science, engineering, and education enterprise. Contract deliverables for this task include:
    - Comparison of SEES solicitations (final report delivered July 2015)
    - Comparative Analysis of SEES and non-SEES programs (in progress, due October 2016)
    - Indicators Report on value of SEES as a portfolio of programs (in progress, due November 2016)
    - Comparison of workforce development and training in SEES and non-SEES programs (due November 2017).
- **Network Analyses** – development of collaboration indicators, influence of participation in SEES programs on individual researchers, and a comparison of networking activities of SEES and non-SEES individuals. Contract deliverables for this task include:

- Collaboration Indicators report (due June 2016)
- Final Report on Influence of Participation in SEES (due March 2017)
- Final Report on Comparison of Networking Activities between SEES and non-SEES Participants (due April 2017).

SECURE AND TRUSTWORTHY CYBERSPACE (SaTC) $149,750,000
+$20,000,000 / 15.4%

Overview
Achieving a secure and trustworthy cyberspace is a challenge of national importance. Organizations, infrastructure, and individuals are increasingly victims of cyber attacks, which result from weaknesses in the technical infrastructure coupled with human behaviors that play to the advantage of attackers. The outcomes are worsened by inadequate knowledge about how to respond to and mitigate these adverse events. As we move to ubiquitous cyber-physical systems and a future Internet of Things (e.g., in transportation systems, smart grids, medical devices, and advanced manufacturing, etc.), this challenge will become even more acute. The trustworthiness of cyberspace is challenged in complex ways, including misinformation, cyber identity verification issues, and the increasing sophistication and co-evolution of attacks and responses. Addressing these problems requires multi-disciplinary expertise in computer science; statistics; mathematics; and social, behavioral, and economic sciences, along with the transition of new concepts and technologies into practice. The NSF-wide Secure and Trustworthy Cyberspace (SaTC) investment supports long-term foundational research and education in cybersecurity and privacy leading to a cybersecure society and providing a strong competitive edge in the Nation's ability to produce high-quality digital systems and a well-trained workforce.

Total Funding for SaTC
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$124.71	**$129.75**	**$149.75**

Goal
The long-term goal of the SaTC investment is to build the knowledge base in cybersecurity that enables discovery, learning, and innovation; leading to a more secure and trustworthy cyberspace. SaTC aims to develop the scientific foundations for cybersecurity and privacy research for years to come through a focus on long-term, foundational research in cybersecurity. More specifically, SaTC looks to broaden the cybersecurity research portfolio to include more cross-disciplinary projects with expertise in computer, computational, statistical, mathematical, social, behavioral, and economic sciences; increase opportunities for implementing new technologies that emerge from the research; expand the number of large, multi-institutional projects that provide high-level visibility to cybersecurity grand challenges; and establish curricular recommendations for new courses, degree programs, and educational pathways that foster innovative approaches to educate and prepare tomorrow's cybersecurity researchers and professionals. The investment aligns with recent federal cybersecurity strategies, including *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*;[1] the government-wide Comprehensive National Cybersecurity Initiative (CNCI); and the recent Cybersecurity Enhancement Act of 2014 (P.L. 113-274).

Approach
The Directorate for Computer and Information Science and Engineering (CISE) leads this NSF-wide effort, and is joined by the Education and Human Resources (EHR), Engineering (ENG), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE) directorates. Each of these organizations supports a research community whose abilities are needed collectively to build the envisioned secure and trustworthy cyber environment, and to prepare the scientists and supporting

[1] https://www.whitehouse.gov/sites/default/files/microsites/ostp/fed_cybersecurity_rd_strategic_plan_2011.pdf

workforce necessary to sustain and improve that environment. The SaTC investment is managed by a Working Group (WG) comprising program directors from the participating directorates.

EHR invests in the CyberCorps®: Scholarship for Service (SFS) program, which supports cybersecurity education and workforce development. Since 2002, SFS has funded more than 2,300 students, and more than 1,700 have graduated and been placed in federal agencies and departments. SFS scholarships are currently available at over 50 institutions of higher education. Furthermore, over 200 SFS capacity-building grants are increasing the ability of the higher education enterprise to produce cybersecurity professionals.

NSF also collaborates with other federal partners on cybersecurity. For example, NSF co-chairs the Networking and Information Technology Research and Development Program (NITRD) Cyber Security and Information Assurance (CSIA) Senior Steering Group (SSG), which provides leadership across the government in cybersecurity R&D by serving as a forum for information sharing and cross-agency agenda setting. SaTC activities are also coordinated with other agencies through NSF's participation in the CSIA Interagency Working Group (IWG) and the Special Cyber Operations Research and Engineering (SCORE) IWG. In addition, NSF and the Department of Education (ED) co-lead the Formal Cybersecurity Education component of the National Initiative for Cybersecurity Education (NICE).

The SaTC investment has the following objectives:

Inducing Change
SaTC investments induce change by investing in research that:

- Leads to a better understanding of the motivations, incentives, and behaviors of users, attackers, and defenders;
- Provides the foundations and tools for privacy, confidentiality, accountability, and anonymity, as well as extraction of knowledge from massive datasets without compromising societal values;
- Provides the foundations and tools for privacy, confidentiality, accountability, and anonymity, as well as extraction of knowledge from massive datasets without compromising societal values; and
- Advances the design and implementation of software that exhibits resiliency in the face of an attack, the design and composition of software components into large-scale systems with known security properties, and the design of reliable systems including attention to behavior and human factors.

Developing Scientific Foundations
SaTC investments develop the scientific foundations of cybersecurity by supporting research on:

- Digital systems that can resist attacks, including a range of cryptographic algorithms and statistical tools that can withstand attacks from novel computing engines, such as quantum computers;
- The mathematical and statistical theory and methodologies required to model and predict the behavior of large-scale, complex systems; assuring that the large-scale computations in many fields of research are not vulnerable to manipulation or compromise; and develop and implement improved cybersecurity defenses for scientific environments and cyberinfrastructure; and
- The scientific foundations necessary to understand how individuals, groups, organizations, and others make decisions in the realm of cybersecurity as well as market-based approaches to align incentives for investments, efficiently share risks, and internalize externalities.

Maximizing Research Impact
The SaTC investment maximizes research impact by:

- Ensuring that the Nation's populace understands the security and privacy characteristics and limitations of the digital systems on which they rely daily;

- Coordinating with NSF's Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) investment to support foundational research in cybersecurity issues arising in advanced manufacturing, robotics, and critical infrastructure, such as smart grids;
- Investigating opportunities and challenges in organizational alliances around cybersecurity;
- Examining alternative governance mechanisms, for example, private-public partnerships and international agreements.

<u>Accelerating Transition to Practice</u>
SaTC investments are transitioning successful basic research results and commercial innovations into early adoption and use by:

- Allowing NSF cyberinfrastructure to serve as a premier proving ground and state-of-the-art environment for advancing cybersecurity solutions and moving them into technical and organizational practice;
- Providing insight and incentives into the process for innovation diffusion and adoption at the societal, organizational, group, and individual levels; and
- Driving innovation experimental deployment and implementation, resulting in fielded capabilities and innovations of direct benefit to campus networks, systems and environments supporting NSF science and engineering research and education environments.

<u>Cybersecurity Education:</u>
SaTC activities address important issues in the education and preparation of tomorrow's cybersecurity workforce by:

- Promoting innovation, development, and testing and evidence-gathering of new curricula and learning opportunities;
- Increasing the number of qualified students entering the fields of information assurance and cybersecurity and information assurance; and
- Enhancing the capability of the U.S. higher education enterprise to produce professionals in these fields to meet the needs of our increasingly technological society.

Investment Framework

SaTC Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Computer and Information Science and Engineering	$70.56	$70.50	$70.50
Education and Human Resources	45.04	50.00	70.00
Engineering	3.25	3.25	3.25
Mathematical and Physical Sciences	1.86	2.00	2.00
Social, Behavioral, and Economic Sciences	4.00	4.00	4.00
Total	**$124.71**	**$129.75**	**$149.75**

FY 2015 – FY 2016

In FY 2015, CISE, EHR, ENG, MPS, and SBE jointly issued a revised SaTC solicitation to continue to seek proposals that expand the research and development frontiers for a secure and trustworthy cyberspace. The revised SaTC solicitation offered a new size category for projects: "Large" (up to $3.0 million per award and up to five years in duration). This new category aims to provide portfolio balance through investments in a diverse set of collaborations focused on large-scale Trustworthy Computing (TwC) research, SBE research, or integrated TwC/SBE efforts. In summer 2015, NSF issued the FY 2016 SaTC program solicitation for Small, Medium, and Large proposals.

Building on the results of a Science of Cybersecurity workshop held in FY 2014, SaTC funded projects in FY 2015 focused on the scientific foundations of cybersecurity. NSF also held a cross-agency workshop in FY 2015 to review progress made in developing a science of cybersecurity, and to propose ways in which needs and results can be communicated more effectively to stakeholders from academe, industry, and government. In FY 2016, SaTC is funding innovative projects in the science of cybersecurity, the science of privacy, cybersecurity for cloud computing, and cybersecurity for cyber-physical systems. These projects include foci on big data analytics for cybersecurity and software engineering for cybersecurity.

SaTC also continued funding community-building workshops with interagency representation. For example, in FY 2015 SaTC jointly funded a workshop with the Department of Homeland Security (DHS) to identify ways to transition NSF- and DHS-funded cybersecurity research into practice.[2] In addition, a SaTC workshop titled, *Privacy in the Era of Big Data*, brought together experts in the domains of big data and privacy to develop a research agenda for better understanding and promoting privacy in an era of big data.[3] In FY 2016, SaTC will sponsor additional community workshops to explore mathematical research necessary for advancing cybersecurity. NSF will also hold a series of workshops with key stakeholders to identify research areas based on the recommendations contained in the National Privacy Research Strategy that is expected to be published in FY 2016. One of these workshops will be held in collaboration with other federal agencies, and will seek to review progress toward developing a science of privacy and to propose ways that research needs and results can be better communicated across government, academe, and industry.

Education and training continued to be a major component of SaTC. EHR continued funding SFS capacity-building awards, which focus on recruiting and retaining underrepresented minorities, women, first-generation undergraduate students, low-income students, and/or veterans. EHR also continued funding SFS awards to and partnerships with minority-serving institutions and two-year colleges. In FY 2015, SFS continued to work with community colleges designated as Centers of Academic Excellence in Information Assurance 2-Year (CAE2Y) by providing funds for two Advanced Technological Education (ATE) centers for cybersecurity education. SFS plans to launch two related efforts in FY 2016, one to increase the number of community colleges holding the CAE2Y designation, and one to create and disseminate a cybersecurity-themed version of the Advanced Placement® Computer Science Principles course for use in community colleges. In FY 2016, SFS will support research and development in cybersecurity education to encourage and test innovative approaches for the preparation of cybersecurity professionals in formal and informal settings. This effort will include support for the development and assessment of learning modules and approaches for cybersecurity education that can be incorporated into computer science instruction, quantitative and scientific literacy curricula, and science and engineering programs for undergraduate and graduate students who will need basic understandings of cybersecurity relevant to their domains. NSF will also support foundational educational research to examine basic concepts and instructional approaches for cybersecurity.

[2] http://soc.southalabama.edu/TTP/images/TTPWorkshopExecutiveSummary.pdf
[3] http://www.fox.temple.edu/cms/wp-content/uploads/2014/11/White-Paper-for-Privacy-in-an-Era-of-Big-Data-Workshop.pdf

In FY 2015, SaTC focused on new ways to promote innovation, development, and assessment of new learning opportunities in order to create and sustain an unrivaled cybersecurity workforce. NSF also supported in FY 2015 and FY 2016 large-scale cybersecurity competitions through collaborations with California State Polytechnic University-Pomona's National Cybersecurity Sports Federation, which provides a shared pathway for students to learn cyber competitions the way athletes learn a sport.

Following a FY 2014 Cybersecurity Education workshop[4] that brought together computer science educators and cybersecurity researchers, NSF funded high-risk/high-reward collaborative projects to develop innovative approaches to advance cybersecurity education.

Broadening the SaTC research community is critical to facilitating advances in cybersecurity research. Building on the successes of workshops held in FY 2013 and FY 2014, a third workshop for aspiring SaTC principal investigators (PIs) was held in FY 2015. The goal was to educate potential SaTC researchers on the priorities of the program and components of successful research projects. In FY 2016, NSF will continue to use this approach to bring new researchers with a broad set of talents and interests into the SaTC PI community.

NSF convened its second biennial principal investigators' (PI) meeting, bringing together over 400 NSF-funded cybersecurity researchers and educators along with representatives from industry, and government, including other federal agencies. The PI meeting served as an opportunity for assessing progress through previous and active cybersecurity research and education investments, and to identify emerging directions including novel interdisciplinary areas. In addition, in order to facilitate transition of research to practice, a session at this PI meeting was dedicated to educating SaTC PIs about other NSF programs that focus on transition to practice, such as the Accelerating Innovation Research (AIR) activity within NSF's Partnerships for Innovation (PFI) program and NSF Innovation Corps (I-Corps™).

In FY 2015 and FY 2016, NSF continued its partnerships with industry in the domain of cybersecurity. In FY 2015, NSF and Intel Corporation jointly funded two large-sized projects with the goal to foster novel, transformative, multidisciplinary approaches that ensure the security of current and emerging cyber-physical systems. NSF also partnered with the Semiconductor Research Corporation (SRC) in FY 2015 and FY 2016 through the Secure, Trustworthy, Assured and Resilient Semiconductors and Systems (STARSS) perspective within the SaTC solicitation. NSF and SRC are jointly funding projects focused on strategies, techniques, and tools that avoid and mitigate vulnerabilities and lead to semiconductors and systems that are resistant and resilient to attack or tampering.

In FY 2015 and FY 2016, NSF partnered with the US-Israel Binational Science Foundation (BSF) to support collaborations between U.S. and Israeli researchers focused on foundational research in all areas of cybersecurity. This partnership is yielding international teams that are seeking to enhance the security and trustworthiness of cyberspace in the long term.

FY 2017 Request

The following activities are planned:

- The SFS program will be expanded and will lay groundwork for SFS alumni to be available over the course of their careers to serve the federal government to help rapidly respond to cybersecurity challenges.
- SaTC will continue to fund innovative projects in the science of security and privacy, security for cloud computing, as well as big data analytics for cybersecurity, improved cryptographic algorithms, and software engineering for cybersecurity.

[4] https://research.gwu.edu/sites/research.gwu.edu/files/downloads/CEW_FinalReport_040714.pdf

- SaTC will also support research on the security of cyber-physical systems, as well as low-cost and/or low-effort approaches for securing systems such as web services and the emerging Internet of Things (IoT)
- SaTC will coordinate with the NSF-wide CEMMSS investment and will include a focus on secure advanced manufacturing (including cyber-manufacturing) systems, robotics, and critical infrastructure such as smart grids.
- NSF will build upon existing, and develop new, partnerships with other federal agencies, industry, and international organizations to effectively achieve long-term goals related to SaTC.
- NSF will continue growing the cybersecurity research community to include more researchers who cross the boundaries between computer science, engineering, social, behavioral, and economic sciences, statistics, and mathematics.
- SaTC also will continue to focus on transitioning to practice research results ready for experimental deployment, early adoption, commercial innovation, or implementation in cyberinfrastructure through support of TTP projects. NSF will also support at least one experimental testbed to enable cybersecurity researchers to experiment in realistic environments.
- As part of SaTC's goal to enhance the capacity of the U.S. higher education enterprise to produce cyber professionals to meet societal needs, the investment will support initiatives by diverse groups of computing professionals representing academic institutions and professional societies to develop curriculum guidelines and a case for accreditation for a baccalaureate in "Cyber Science." It is expected that the Accreditation Board for Engineering and Technology, Inc. (ABET) will introduce this new accreditation in FY 2018, and that it will become a parent domain for the cybersecurity field.
- Additionally, SaTC will continue to promote the development of, and related research about, new curricula and learning opportunities to augment the cybersecurity workforce with focused efforts to recruit and retain underrepresented minorities, women, first-generation/low-income students, and/or veterans.
- SaTC will also support education and professional development through a new Transition to Education (TtE) mechanism. Through TtE, research results in the science of cybersecurity and designed-in security will be incorporated into relevant course curricula that will be implemented, assessed, and improved in a variety of settings. Such efforts will be supported using TtE supplements and options. TtE will be analogous to the Transition to Practice component of SaTC.
- SaTC will continue to build the cybersecurity research community by holding the next in a series of biennial PI meetings with representation from academe, industry, and government, including other federal agencies, focusing on the science of cybersecurity and novel interdisciplinary areas of research. The PI meeting will continue to showcase successful TTP/AIR/I-Corps™ projects resulting from SaTC investments. NSF also will hold a PI meeting with cybersecurity for cyber-physical systems awardees to review progress and identify critical unaddressed problems and directions.

FY 2018 and Beyond

Building on the knowledge base developed during the previous years, NSF plans to continue to focus on game-changing research and education, and the development of digital systems that are resistant to attacks through the SaTC program. In coordination with the NSF-wide CEMMSS investment and its successor activities, SaTC will include a focus on secure advanced manufacturing systems, robotics, and critical infrastructure such as smart grids. SaTC will also focus on transitioning to practice research results ready for experimental deployment, early adoption, commercial innovation, or implementation in cyberinfrastructure. In addition, SaTC will build upon existing, and develop new, partnerships with other federal agencies, industry, and international organizations to achieve its long-term goals effectively. The cybersecurity research community is expected to continue growing to include more researchers who cross the boundaries between computer science, engineering, economics, social and behavioral sciences, statistics, and mathematics.

NSF will continue to promote the development of, and related research about, new curricula and learning opportunities to augment the cybersecurity workforce, with focused efforts to recruit and retain underrepresented minorities, women, first-generation/low-income students, and/or veterans.

Evaluation Framework

NSF has engaged the Science and Technology Policy Institute (STPI) to conduct a program evaluation feasibility study for the SaTC program. This evaluation feasibility study is examining the baseline portfolio of SaTC investments and identifying metrics to measure progress towards goals as part of an impact assessment. The evaluation feasibility study was initiated in the fourth quarter of FY 2012, and NSF expects to receive a final report in FY 2016.

This feasibility study has developed a plan for an impact assessment of the SaTC investment. The approach outlined below has been followed:

- STPI held meetings with the SaTC working group and SaTC management to examine the past and current award portfolios, including an assessment of the components of the portfolio by technical and scientific content. In addition, as part of this portfolio analysis, STPI synthesized various recommendations from federal advisory boards and stakeholder communities on how to structure future cybersecurity investments.
- STPI developed a logic model to help NSF track progress toward its major scientific objectives (e.g., discovery of the root causes of threats and attacks and continuous investment in transformational approaches that improve the security of cyberspace; and development of a systematic scientific approach to cybersecurity, including discovery of fundamental principles).

Based on the results, NSF and a third-party contractor will begin developing the appropriate plan for assessing progress across NSF's SaTC activities, following the framework NSF is establishing in consultation with STPI.

The Office of Personnel Management's Human Resources Solution (HRS) conducted an evaluation of the SFS program, primarily focusing on the program's scholarship and capacity building tracks. HRS and NSF are finalizing a report on this evaluation.

Going forward, program monitoring and evaluation activities will be coordinated to reduce the burden on principal investigators, scholarships recipients, and program administrators. HRS will consult with NSF on the program evaluation in ways that maintain the integrity and independence of the evaluation while ensuring that the evaluation is sensitive to the program's objectives, goals, mission, vision, and any pending legislation or executive level initiatives. The intent of the SFS program monitoring system is to provide a description of the implementation and selected desired outcomes of the program over time and to address the issues raised by the GAO report, *Cybersecurity Human Capital: Initiatives Need Better Planning and Coordination*, GAO-12-8, November 2011.[5]

[5] www.gao.gov/assets/590/586494.pdf

UNDERSTANDING THE BRAIN (UtB) $141,620,000

-$5,310,000 / -3.6%

Overview

Understanding the brain (UtB) is one of the grand scientific challenges at the intersection of the physical, life, behavioral, and engineering sciences. The National Research Council report, "*Research at the Intersection of the Physical and Life Sciences*" (2010),[1] identified "Understanding the Brain" as one of the top five grand challenges for research that will significantly benefit society. The National Academy of Engineering has also recognized "*Reverse-Engineer the Brain*" as a Grand Challenge for Engineering (2008).[2]

Many incremental advances in research and technology in recent decades are elucidating individual elements of the nervous system and brain and their relationships to individual cognitive processes and behaviors. However, there remains much to discover to attain a comprehensive understanding of the general principles underlying how cognition and behavior relate to the brain's structural organization and dynamic activities, how the brain interacts with its environment, and how the brain can recover from lost functionality.

The critical challenge to this comprehensive understanding is to integrate research and innovation across multiple scales of space and time, from molecular, physical (e.g., biophysical and biochemical), physiological, and genetic to cognitive and behavioral, with the ultimate goals of establishing integrative, quantitative, and predictive theories of brain structure and function.

To address this challenge, NSF is making major investments in collaborative fundamental science, in innovative enabling technologies, and in workforce development to accelerate discovery and revolutionize our understanding of the brain. NSF is leveraging and substantially expanding its investments in high-risk/high-reward exploratory and transformational scientific and engineering research with emphasis on integration across scales and disciplines. Novel experimentation, multimodal data integration, and theoretical developments that span the molecular, biophysical, biochemical, systems, genetic, organismal, and social scales will elucidate the mechanisms linking dynamic brain activity to behavior and physiology of the whole organism in its environmental context. New conceptual and physical tools with the associated technologies will expand the limits of detection, refine the level of experimental manipulation, and improve computational capability, allowing a fuller characterization and analysis of temporal and spatial patterns of the activity of networks of neurons that drive behavior. Other investments will aim to improve education through discoveries in the neural bases of learning, and enhance our understanding of how the brain adapts to changing environments.

Total Funding for Understanding the Brain (UtB)

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
UtB	**$109.39**	**$146.93**	**$141.62**
BRAIN	*$50.12*	*$73.46*	*$74.16*

NSF is uniquely positioned to advance research on understanding the brain by bringing together a wide range of scientific and engineering disciplines to reveal the fundamental principles underlying brain structure and function. The co-mingling of these disciplinary and interdisciplinary fields is expected to

[1] www.nap.edu/openbook.php?record_id=12809
[2] www.engineeringchallenges.org/File.aspx?id=11574&v=ba24e2ed

yield enhanced understanding of the brain, cognition, and behavior, through the development of new technologies and theories. NSF has been a catalyst for transformative breakthroughs in brain research and related technologies; for example, the fundamental research that led to the development of optogenetics, the CLARITY transparent brain preservation technique, brain-machine interface systems, and the first FDA-approved artificial retina began with NSF support. In addition, NSF's capacity for enabling integrative activities in neuroscience at a global scale is exemplified by NSF's long-term supporting role in the International Neuroinformatics Coordinating Facility (INCF).

In 2012, Congress encouraged NSF to create a cross-foundation activity in cognitive science and neuroscience, and also encouraged the White House to form the Interagency Working Group on Neuroscience (IWGN) under the National Science and Technology Council, which is co-chaired by NSF. In FY 2013, the President announced the multi-agency Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, with NSF as one of the lead participating agencies. The Understanding the Brain activity draws together and consolidates NSF's ongoing activities in cognitive science and neuroscience and the BRAIN Initiative.

Since its inception, this cross-foundation activity has brought the relevant but disparate scientific communities together, and that has resulted in the funding of novel collaborative efforts and innovative research and technology awards. In FY 2013, NSF released a cross-foundation Dear Colleague Letter (DCL) "Accelerating Integrative Research in Neuroscience and Cognitive Science (AIR-NCS)" and funded nine new Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) awards and one new Research Coordination Network (RCN) as a result. In FY 2013 and FY 2014, NSF sponsored a series of workshops across the participating science and engineering directorates to provide input on research priorities and engage in preparatory collaborative activities. NSF used the resulting reports, white papers, and research articles to develop this multi-year roadmap of investment priorities and to devise targeted calls for research proposals. For example, in FY 2014 the Directorate for Biological Sciences (BIO) published a DCL for Early-concept Grant for Exploratory Research (EAGER) proposals for "catching circuits in action" projects to apply innovative neurotechnologies to study neural circuits responsible for cognition and behavior. This resulted in 36 highly interdisciplinary awards focused on elucidating the functional roles of neural circuits, funded by multiple NSF directorates. These awardees were invited to a joint meeting with the first cohort of NIH BRAIN Initiative awardees following the annual meeting of the Society for Neuroscience in Washington, D.C. as part of the President's BRAIN Initiative.

Goal

The overall goal of UtB is to enable scientific understanding of the full complexity of the brain in action and in context. This multi-year goal is being pursued across the four ongoing priority areas:

1. *Develop innovative neurotechnologies to monitor and analyze brain activity, and new tools, experimental approaches, theories, and models to integrate neuroscience information across scales and scientific disciplines.*

   This priority area is aligned with the objectives of the Administration's BRAIN Initiative. These objectives are focused on development of innovative technologies, tools and instrumentation, computational infrastructure, theory, and models that will accelerate the integration of knowledge across experimental scales from molecular to behavioral; across multiple science, engineering, and computational disciplines; and across species and lifespans. Expected outcomes include the development of new neurotechnologies, predictive models, and theories of brain and nervous system function that can guide follow-on experimental research and foster further technical and theoretical achievements.

2. *Identify the fundamental relationships among neural activity, cognition, and behavior.*

   This priority area aims to foster increased understanding of the causal relationships between neuronal activity in the brain, cognitive processes, and behavior. Advancements in this area require increased collaboration among the neuroscience, neuroengineering, cognitive science, science, technology, engineering, and mathematics (STEM) education, and behavioral and social science disciplines; adoption of innovative technologies and methods to monitor and manipulate brain activity, such as the recent development of optogenetics; and the utilization of cyberinfrastructure platforms and computational tools for performing multi-scale analysis of neuroscientific and behavioral data. NSF-planned investments are designed to provide an agile means for research teams to form around specific behavioral paradigms and adapt and/or develop technologies and models. Expected outcomes include an increase in the number of such teams working together on specific neural-behavioral paradigms utilizing advanced methods and models.

3. *Transform our understanding of how the brain responds and adapts to changing environments and recovers from lost functionality.*

   This priority area aims to expand support for exploring the links among the environment, behavior, and brain function, as well as the enhancing and restorative neurotechnologies that can be brought to bear in these areas. NSF research investments will catalyze the formation of new teams to elucidate basic brain mechanisms and their relationships to complex environments (including educational environments), cognition and behavior, and related neuroengineering. The expected outcome is measurable progress in developing specific mappings between brain functional/structural changes, changes in behavior and cognition, and changes in psychosocial, external physical, and technological environments; and acceptance of those mappings more widely in the community via citation and use/re-use.

4. *Train a new generation of scientists, engineers, and educators for a transdisciplinary, globally competitive workforce in neuroscience and neuroengineering.*

   This priority area focuses on development of a scientific workforce for understanding the brain that is better prepared for interdisciplinary and global collaboration, data analysis and sharing, and adoption of new and innovative technologies, tools, and models. In order to transform the workforce, the activities funded under priority areas one to three will require special training and professional development for multi-disciplinary research and international collaboration. The expected outcome will be a future workforce fully engaged in and facile with technologies and data science to understand the brain in action and in context.

Approach

Using existing mechanisms including workshops, DCLs, RCNs, targeted solicitations, and special mechanisms such as EAGERs and Ideas Labs, NSF will bring together the diverse relevant scientific communities in biology, chemistry, behavior, cognition, computational and information science, education, engineering, physics, psychology, mathematics, and statistics to identify scientific priorities and needed research infrastructure, establish cross-disciplinary standards, integrate data and methods, and catalyze the development of conceptual and theoretical frameworks. This will be accomplished through:

Specific Investment 1: Integrative and transdisciplinary team-based brain research.

NSF will seek proposals from interdisciplinary teams of researchers poised to promptly address targeted issues, such as innovative experimentation in realistic and complex environments; neurotechnology development; computational modeling and simulation; educational applications of neuroscience and neuroengineering research; and quantitative theory development. Such teams will also contribute to defining requirements for cyberinfrastructure and analytic tools required to address the expected data surge from these experimental, modeling, and theoretical efforts. One major objective of these investments is to establish truly transdisciplinary team-based brain research − integrated collaborative research environments that rise above existing disciplines. Examples of expected outcomes include noninvasive or minimally invasive imaging technologies for brain mapping, and advanced neuroprosethetics for neuron repair or regeneration based on neuron decoding including deciphering neural coding and circuits and mechanisms underlying dynamic decisions and communication within and across scales in the brain.

Specific Investment 2: Data science, infrastructure, and tool development for understanding the brain.

NSF will provide new opportunities for building infrastructure, cyberinfrastructure, and analytic capabilities for data integration and interpretation across scales and disciplines, with the objectives of transforming data to knowledge for advances in cognitive science, neuroscience, neuroengineering research and education. Proposals will also be sought to address outcome goals of establishing policies and community practices for data management, open access, data sharing, and methods for exploiting large-scale neuroscience and behavioral data. This will be coordinated within the context of further developing the concept of a National Brain Observatory. A major NSF objective will be to encourage stronger connections with other NSF-funded communities that are dealing with similar Big Data issues and multi-modal data integration, such as those focused on earth, ocean, and climate observing, high energy physics, astronomy, and related large-scale computing. NSF will fund planning workshops and other community engagement activities to identify and clarify specific needs for infrastructure and analytic tools.

Specific Investment 3: Specialized training and professional development in multidisciplinary and international research and large-scale data management and analysis.

To develop a scientific workforce that is better prepared for interdisciplinary and global collaboration in understanding the brain, NSF will provide opportunities for training and professional development of supported personnel (students, postdoctoral scholars, and principal investigators) in areas of multidisciplinary research and international collaboration. Opportunities for multidisciplinary training will require mentoring and professional activity in collaboration and co-located collaborations with experts from intellectually distinct disciplines. Supporting this effort, the NSF Research Traineeship (NRT) program will feature Understanding the Brain as one of its emphasis areas. For international training, opportunities must be provided for students and professionals to train and/or collaborate abroad for a defined period of time. Award supplements will be tracked separately for evaluation purposes.

Investment Framework

UtB Funding by Directorate
(Dollars in Millions)

Dir/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	$38.48	$44.38	$46.00
CISE	16.50	29.72	23.58
EHR	5.00	11.00	11.00
ENG	11.00	16.75	16.75
MPS	15.44	19.49	18.70
SBE	22.97	25.00	25.00
OISE	-	0.59	0.59
Total, UtB	**$109.39**	**$146.93**	**$141.62**
BRAIN	*$50.12*	*$73.46*	*$74.16*

Totals may not add due to rounding.

FY 2015 – FY 2016

In FY 2015, NSF invested $50.12 million in the BRAIN Initiative to catalyze fundamental research and new collaborations across neuroscience, neuroengineering, and cognitive science. An additional $59.27 million, through core research activities, focused on accelerating fundamental research and associated development of new technologies for neuroscience and neuroengineering, bringing the total for UtB to $109.39 million. FY 2015 included a new solicitation sponsored by the Directorates for Social, Behavioral, and Economic Sciences (SBE); Computer and Information Science and Engineering (CISE); Engineering (ENG); and Education and Human Resources (EHR) on Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS), and an Ideas Lab, "Cracking the Olfactory Code," sponsored by BIO and the Directorate for Mathematical and Physical Sciences (MPS) in partnership with the Janelia Farm research campus of the Howard Hughes Medical Institute. The NSF-NCS solicitation resulted in an investment of approximately $13 million for 16 new awards as part of NSF's support for integrative, fundamental brain research and the BRAIN Initiative. Also in FY 2015, EHR and SBE funded a cross-agency White House workshop on neuroscience and learning, and SBE, ENG and CISE released a DCL through the Industry/University Cooperative Research Centers (I/UCRC) program to foster collaborations between industry and academia in the field of brain imaging and in identifying structure-behavior relationships. An interagency working group was formed to initiate conceptual planning for a National Brain Observatory. A report was submitted to Congress on their current planning efforts.

In FY 2016, NSF increases its investment to $146.93 million for the UtB activity, with $73.46 million of these funds devoted to projects related to the BRAIN Initiative, $3.0 million of which will be directed to furthering the development of the concept of a National Brain Observatory. These investments will drive integration of research at multiple scales of analysis and accelerate the development of new theoretical, experimental, and analytical approaches, including cyberinfrastructure platforms, computational and data-enabled modeling and tools, and new neural engineering and technology research and development. Funding will also enable transformative scientific progress toward understanding of the functional dynamics of the brain and complex neural systems, and their interactions with changing physical, technological, and social environments throughout the lifespan.

To understand the full complexity of the brain, it will be crucial to increase collaborations among relevant scientific communities, which have traditionally focused on discipline-specific experimental questions. Consequently, FY 2016 investments will also fund new interdisciplinary and transdisciplinary team formation and workforce development through the development of up to two solicitations sponsored by unique combinations of our disciplinary directorates. In FY 2016, SBE, CISE, ENG, and EHR reissued the solicitation Integrative Strategies for Understanding Neural and Cognitive Systems. Funding will also support increases in interagency collaboration, coordination, and communication through the BRAIN Initiative and the efforts of the IWGN. In FY 2016, NSF takes a leadership role in international coordination through its support for a conference entitled, "Coordinating Brain Projects Across the Globe," that will be co-sponsored by the Kavli Foundation and organized to coincide with the United Nations Meeting of the General Assembly in September of 2016. The purpose of this conference is to bring together government representatives and leading scientists from countries already collaborating with the U.S. and/or making major investments in neuroscience research to exchange ideas about activities and identify opportunities to coordinate efforts where possible.

FY 2017 Request

In FY 2017, NSF total investment in the UtB activity is $141.62 million, a 3.6 percent reduction. Within this amount, $74.16 million will support activities related to the BRAIN Initiative. NSF will maintain the UtB focus initiated in FY 2015 and FY 2016 by continuing to employ investment strategies designed to enable the transformational research, engineering, infrastructure development, and training required to accomplish the overall multi-year goal across the priority areas identified earlier. These activities will include continuing efforts to further the development of the concept of a National Brain Observatory.

FY 2018 and Beyond

The NSF-wide UtB Coordinating Group will assess NSF's UtB investment using the assessment metrics discussed below to determine which priority areas had the highest impact on the field and how best to build upon them. The results of this assessment will guide NSF's UtB investment in FY 2018 and beyond.

Evaluation Framework

The NSF-wide UtB Coordinating Group will oversee evaluation of the progress on scientific and programmatic activities. Assays of success for each priority area below will be compared against the expected outcomes described above, using measures including:

- Priority Area 1: level of deployment and adoption of innovative technologies by the scientific community via reuse and citations;
- Priority Area 2: increases in the number of transdisciplinary teams funded to work and publish in this area;
- Priority Area 3: acceptance by the research community of new mappings between brain functional/ structural changes and identified changes in psychosocial, external physical, technological, and educational environments; and
- Priority Area 4: number of participants, and demographics of collaborations in publications before and after the investment period.

The progress of the implementation of this investment will be monitored and reviewed quarterly to ensure that it is on track as part of the FY 2016 Performance Goal 1: Ensure that Key Program Investments are on Track. This aligns with all objectives of Strategic Goal 1: Transform the Frontiers of Science and Engineering and Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education. For more information about monitoring key program investments, see the FY 2016 Annual Performance Plan in the Performance chapter of NSF's FY 2016 Budget Request to Congress[3] and the FY 2017 Annual Performance Plan in the Performance chapter of this Budget Request.

[3] www.nsf.gov/about/budget/fy2016/pdf/57_fy2016.pdf

IMPROVING UNDERGRADUATE STEM EDUCATION (IUSE) $109,000,000 +$4,000,000 / 3.8%

Overview

The National Science Foundation (NSF) Improving Undergraduate STEM Education (IUSE) initiative is a Foundation-wide integrated framework for the agency's investments in undergraduate science, technology, engineering, and mathematics (STEM) education. In order to prepare a diverse and innovative workforce[1] and a STEM-literate public, NSF has a leadership role in accelerating the quality and effectiveness of the education of undergraduates in all STEM fields. NSF investments in undergraduate STEM education are coordinated through the IUSE framework to enhance coherence and impact and to use shared metrics and evaluation approaches where appropriate. NSF investment in undergraduates and their education occurs across all directorates and addresses both general trends such as the use of approaches to promote "active" learning in undergraduate STEM instruction, the increase of undergraduate research courses, and attention to undergraduate degree completion; as well as specific disciplinary needs, such as the need to reform the "middle years" in the undergraduate preparation of professional engineers, the need to recruit more women and minorities into majors in computer science, and the data science preparation of undergraduates in the geosciences and the biological sciences.

IUSE ideas are informing cross-agency implementation of the undergraduate strategic objectives in the National Science and Technology Council's *Federal STEM Education 5-Year Strategic Plan,*[2] an effort co-led by NSF and the Department of Energy. The importance of the undergraduate experience for preparing a diverse STEM and STEM-capable workforce equipped for innovation, and a STEM-literate public ready to support and benefit from the progress of science, is described in a number of key reports and documents.[3,4] NSF, with its mission to advance science, engineering, and education, plans to invest $109.0 million in FY 2017 through coordinated investments both across and within directorates, aligned with the IUSE framework for improving undergraduate STEM learning.

Total Funding for IUSE

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$102.82	**$105.00**	**$109.00**

Goal

NSF investments are catalyzing improvement in undergraduate STEM education to achieve high quality STEM learning for all undergraduates and to build talent to increase degree completion for all STEM majors. NSF undergraduate investments map to one or more of the three IUSE goals:

- **Improve STEM learning and learning environments.** Improve the knowledge base for defining, identifying, and implementing innovative undergraduate instruction in all NSF-supported disciplines in order to improve student learning and foster widespread use of evidence-based resources and pedagogies in undergraduate STEM education.

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[1] National Science Board (2015). *Revisiting the STEM Workforce*. Arlington, VA: National Science Board www.nsf.gov/nsb/publications/2015/nsb201510.pdf

[2] www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

[3] President's Council of Advisors on Science and Technology (2012) *Engage to Excel*: *Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics,* www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf

[4] Coalition for Reform of Undergraduate STEM Education (2014) *Achieving Systemic Change: A Sourcebook for Advancing and Funding Undergraduate STEM Education*. Washington, DC: Association of American Colleges and Universities.

- **Broaden participation and institutional capacity for STEM learning.** Increase the number and diversity of undergraduates recruited and retained in STEM fields and the number of available career pathways using successful, evidence-based strategies to broaden participation and by growing that evidence base.
- **Build the STEM workforce for tomorrow.** Improve the preparation of undergraduate students so that they can succeed as productive members of the future STEM and STEM-capable workforce, regardless of career path, and be engaged as members of a STEM-literate society.

Approach

Six principles guided the development of the IUSE framework and continue to inform decision-making about strategic investments to achieve the three IUSE goals. The IUSE principles are listed below:

- Federal investment in undergraduate STEM education is critical to the development of the Nation's scientific workforce and NSF has a leading role in this area.
- NSF investments in undergraduate education will be focused, strategic investments that address the greatest challenges in U.S. undergraduate STEM education.
- The IUSE portfolio represents coordination among all directorates, while respecting distinct disciplinary opportunities, challenges, and needs.
- IUSE is informed by input from multiple sources, including the STEM disciplines and education research.
- Development and future growth of the IUSE portfolio will be based on demonstrated impact and effectiveness of NSF investments.
- The IUSE framework will accommodate all NSF investments in undergraduate education and will be aligned with agreed-upon, corresponding directorate goals.[5]

Investment Framework

The IUSE framework uses findings from research and evaluation on STEM learning and education, as well as innovative models and approaches that have been developed in specific disciplines, to address challenges common across all undergraduate STEM education, as well as within specific disciplines. NSF IUSE core investments also serve as test beds for continued building of evidence for improvement across all IUSE investments. NSF IUSE-affiliated programs are positioned to connect to and benefit from, as well as inform, the core activities. The framework draws upon a knowledge base accumulated from decades of research, development, and best practices in STEM undergraduate education.[6,7,8,9] New and ongoing investments within the IUSE portfolio will integrate theories and findings from education research with attention to the needs and directions of frontier science and engineering research. New knowledge about learning and implementation of promising models will be valuable in improving the undergraduate preparation of a diverse STEM workforce.

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[5] All undergraduate programs have now been mapped to the framework and placed into two categories: 1) the IUSE core programs that were developed over the FY 2014 – FY 2016 period as part of the agency-wide initiative, and 2) affiliate programs that are aligned with the framework, both informing and being informed by the work across both program categories. All are connected by their commitment to the IUSE principles.

[6] National Research Council (2012) *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: National Academies Press, www.nap.edu/catalog.php?record_id=13362

[7] National Research Council (2015) *Reaching students: What research says about effective instruction in undergraduate science and engineering*. Washington, DC: National Academies Press, www.nap.edu/download.php?record_id=18687

[8] Bailey, T., S. S. Smith, & D. Jenkins (2015) *Redesigning America's community colleges: A Clearer path to student success*. Cambridge, MA: Harvard University Press

[9] Smith, D. (ed.) (2015) *Vision and change in undergraduate biology education: Chronicling change, inspiring the future*. Washington, DC: AAAS, http://visionandchange.org/files/2015/07/VISchange2015_webFin.pdf

The IUSE framework relies upon the following five investment strategies mapped onto the three goals, providing a tool to analyze and adjust the portfolio of programs in order to maximize the collective impact of the agency-wide effort:

- **Build core knowledge through research and development (R&D)**: R&D investments through EHR core research will grow the evidence base about how to best improve undergraduate education through education research, including "discipline based education research."[10]
- **Implement and scale evidence-based practices and tools:** These investments will allow for the execution of a program or activity, or the building of a discipline-specific, test-case model, based on core research knowledge; such programs and models can serve as sites for implementation research. Examples are IUSE: GEOPATHS and the Advanced Technological Education (ATE) programs.
- **Catalyze departmental and institutional transformation:** This funding supports design and implementation of models for systemic improvement, such as IUSE/Professional Formation of Engineers: REvolutionizing Engineering and Computer Science Departments (IUSE/PFE: RED).
- **Scholarship programs**: This is direct support to STEM students to encourage entry and retention. Examples of these programs are the Robert Noyce Teacher Scholarship (Noyce) and Scholarships in STEM (S-STEM) programs.
- **Disciplinary research experiences for students**: This funding engages students in research and is provided in programs such as Research Experiences for Undergraduates (REU) and International Research Experiences for Students (IRES).

The IUSE program is comprised of core and affiliate programs. These programs are connected by their commitment to the IUSE principles.

- Core programs fund the IUSE investment and are as follows: IUSE: EHR, IUSE: GEOPATHS, Research Coordination Networks: Undergraduate Biology Education (RCN:UBE), IUSE/PFE: RED, and Research in the Formation of Engineers (RFE).
- Affiliate programs are aligned with the IUSE framework, both informing and being informed by the work across both program categories. The affiliate programs are: ATE, Broadening Participating in Engineering (BPE), CyberCorps®: Scholarship for Service (SFS), EHR core research (ECR), Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), I-Corps for Learning, IRES, Louis Stokes Alliances for Minority Participation (LSAMP), REU, Noyce, and TCUP.[11]

IUSE Funding by Directorate

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$1.13	$2.50	$2.50
Computer and Information Science and Engineering	2.00	3.00	2.00
Education and Human Resources	83.84	87.00	92.50
Engineering	4.94	6.00	6.00
Geosciences	10.90	6.50	6.00
Total	**$102.82**	**$105.00**	**$109.00**

[10] Op. cit., National Research Council (2012)

[11] ECR, I-Corps for Learning, RFE, BPE, and SFS are not specifically undergraduate programs; only portions of these are undergraduate investment. For LSAMP, Noyce, and S-STEM, the majority of the investment is at the undergraduate level with some support for other topics and students at other education levels.

FY 2015 – FY 2016

- In FY 2015 and FY 2016, IUSE was implemented through four solicitations. IUSE: EHR had two main investment tracks: Engaged Student Learning and Institutional and Community Transformation. IUSE: GEOPATHS focused on broadening participation and workforce development. IUSE/PFE: RED funded systemic change in the second and third years of engineering and computer science majors to enable engineering and computer science departments to lead the Nation by successfully achieving significant sustainable changes necessary to overcome long-standing issues, including attracting and retaining more women and under-represented minorities, in their undergraduate programs. RCN: UBE scales effective practice through research networks.
- Affiliate programs were aligned with the IUSE framework. In FY 2015, the Directorate for Geosciences (GEO) collaborated with EHR/HRD to establish a new track for Partnerships in Geoscience Education (PAGE) within the TCUP solicitation. The research track of the ATE program was expanded to study retention and transfer in community college populations. EHR's S-STEM program solicitation reflects a program change to a guided-pathways program to support college completion for scholarship recipients in FY 2016.
- In FY 2015, Dear Colleague Letters (DCLs) were used across multiple programs to address specific needs, including further engaging Hispanic-serving community colleges (NSF 15-063 and NSF 15-064). Prospective applicants were invited to develop innovative approaches to increase college opportunity through increased mathematics success, resulting in 30 new awards (NSF 15-026). An I-Corps™ for Learning DCL offered training for grantees to support scaling of effective, evidence-based interventions, tools, resources, and models with an emphasis on reaching groups traditionally underrepresented in STEM fields (NSF 15-050). Hispanic Serving Institutions and I-Corps™ Learning DCLs continue in FY 2016, and EHR will issue a DCL to fund supplements for REU Sites from across directorates to pursue education research or assessment projects of interest to site leaders for improvement of their efforts.
- NSF funded a Maker Summit in FY 2015 and issued an Enabling the Future of Making to Catalyze New Approaches in STEM Learning and Innovation DCL (NSF 15-086).
- NSF-funded National Research Council (NRC) analyses build and spread the IUSE knowledge base. The report on *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering* was released and downloaded by more than 17,000 individuals.[12] A study on undergraduate authentic research experiences, including course-based research was funded by EHR.[13] Two additional studies were funded by EHR, one on indicators of successful undergraduate STEM education, and one study on measuring intrapersonal and interpersonal competencies associated with persistence in college and career satisfaction.[14,15] The Directorate for Computer and Information Science and Engineering (CISE) funded a study[16] to understand the growing enrollments in computer science and engineering, and the implications for computing education at the undergraduate level in the years ahead. GEO funded an NRC workshop to define best practices for using service learning in undergraduate geoscience.[17] The results of all of these efforts will help inform the continuing evolution of NSF's IUSE investments.
- Additional, discipline-specific efforts included the culmination of a decade-long collaboration between The Directorate for Biological Sciences (BIO) and EHR with the release of *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future.*[18] GEO sponsored a

[12] National Research Council (2015) *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering*. Washington, DC: National Academies Press, www.nap.edu/download.php?record_id=18687
[13] http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_090473
[14] http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_167108
[15] http://sites.nationalacademies.org/DBASSE/BOTA/CurrentProjects/DBASSE_160583
[16] NSF award 1551227
[17] NSF award 1544268
[18] Op. cit., Smith, D. (ed.) (2015)

follow-on workshop[19] to a community summit[20] on the Future of Undergraduate Geoscience Education to identify critical competencies and skills required for the future geoscience workforce.
- Specific IUSE FY 2016 emphases include course-based research, scaling evidence-based practices, and broadening participation, specifically in computer science, engineering, and the geosciences.
- The inaugural Community College Innovation Challenge, including a boot camp for finalists and an event on Capitol Hill,[21] was launched in FY 2015 with a second challenge focused on the cross-Foundation priority Innovations at the Nexus of Food, Energy, and Water Systems issued in FY 2016.[22]

FY 2017 Request

In FY 2017, both core and affiliate programs will work in the following IUSE priority areas:
- Develop the capability for gathering data on indicators as a part of IUSE core program monitoring and evaluation by: 1) developing and identifying indicators, metrics, and assessments to measure readiness for and progress toward widespread use of evidence-based resources in undergraduate STEM instruction; and 2) re-instituting the National Survey of Postsecondary Faculty in partnership with the National Center for Education Statistics (NCES).
- Address discipline-specific learning environment needs: 1) BIO will partner with EHR and other directorates to fund development of new curricula that enable 21st century biologists to have the skills to operate in a data-rich world; and 2) CISE will issue a DCL or solicitation focused on developing, prototyping, and implementing new strategies for undergraduate education in computer science, particularly in the face of growing enrollments and interest, and the increasing breath of disciplines from which students are coming to take computer science courses.
- Increase undergraduate research opportunities by: 1) developing research courses and course-based research across the STEM disciplines through the IUSE: EHR solicitation, informed by the NRC study on undergraduate research; and 2) increasing the STEM research and experiential learning opportunities available in NSF-funded large facilities, national laboratories, and centers through the S-STEM program in collaboration with the NSF Graduate Research Internship Program (GRIP).
- SFS funding will begin to lay the groundwork for SFS program scholarship holders to serve as a national resource over the course of their careers.
- Align affiliate programs as appropriate with the IUSE framework: 1) Noyce Teacher Scholarship Program (Noyce) and CyberCorps®: Scholarship for Service will consider guided pathways approaches for broadening participation; 2) Louis Stokes Alliances for Minority Participation (LSAMP), Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), TCUP, ATE, and Noyce will align to support the broadening participation goals of the framework; and 3) a "New-to-IUSE" opportunity will be established in IUSE: EHR for investigators from minority-serving community colleges and investigators from two- and four- year institutions with prior funding from HBCU-UP and TCUP programs.
- Focus on broadening participation: 1) EHR will partner with GEO and CISE to support innovative proposals to increase the percentage of underrepresented racial and ethnic minorities completing geoscience bachelor's degrees in geoscience and women completing bachelor's degrees in computer science; 2) the IUSE: GEOPATHS program will create a broader and more inclusive pathway into careers in the geosciences via research experiences for undergraduates featuring active involvement in field campaigns and at high-level facilities, such as ships, airplanes, and data centers, with employer input about needed skills; and 3) the Directorate for Engineering's (ENG) BPE program will continue to support projects that lead to the understanding of issues and challenges that impact the participation from underrepresented groups specifically in engineering. In FY 2017, IUSE will further advance the broadening participation goal by coordinating with the NSF Inclusion across the Nation of

[19] www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/
[20] www.jsg.utexas.edu/events/files/Future_Undergrad_Geoscience_Summit_report.pdf
[21] www.nsf.gov/news/special_reports/communitycollege/
[22] www.nsf.gov/news/special_reports/communitycollege/

Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) effort, particularly the Networks for STEM Excellence, and will incorporate the "collective impact" approach[23] that is underway in higher education efforts related to college access and improvement.

FY 2018 – FY 2020

As NSF accumulates a broader and deeper set of findings and evidence-based practices for improving undergraduate STEM education, we anticipate increased emphasis in later years in several areas. These include increasing access to undergraduate STEM learning and research experiences through technology, citizen science approaches, and apprenticeship and internship models; transition from pre-college to undergraduate STEM education; and transitions from undergraduate STEM education to the workplace and to graduate school. IUSE will continue to coordinate with the NSF INCLUDES.

Evaluation Framework

The success of IUSE is enhanced by the development of realistic and robust metrics and indicators for gauging progress toward the goals outlined above. These metrics and indicators will be tailored to address progress towards the three IUSE goals: 1) improve STEM learning and learning environments, 2) broaden participation in and institutional capacity for STEM education, and 3) build the STEM workforce of tomorrow. Mapping the investment goals against the five investment strategies (i.e., build core knowledge through R&D, implement and scale evidence-based practices and tools, catalyze departmental and institutional transformation, provide scholarships, and promote disciplinary research experiences) will identify gaps and support analysis of whether or not NSF should invest in gap areas and/or decrease support in other areas. As the IUSE evaluation is planned, consideration will be given to how the different investment strategies – collectively, in combination, and individually – can be optimized to catalyze improvement in undergraduate STEM education. This approach to evaluation is centered on the IUSE framework and will directly inform and improve the collaborative initiative.

While the specific metrics and indicators will need additional consideration, NSF's recent experience in this area points to a number of promising approaches. Specific metrics obtained through monitoring and evaluation can be complemented by metrics from the National Science Board *Science and Engineering Indicators*, including the number of STEM graduates in specific disciplines annually compared with the number of first-year students indicating a desire to major in STEM fields. Existing monitoring and evaluation plans propose to provide data regarding the number of two- to four-year articulation agreements for NSF-funded technician training programs and the relative number of first- and second-year students participating in NSF-funded undergraduate research. As new monitoring plans and evaluation frameworks are developed for IUSE core and affiliated programs, the IUSE AD Council will have responsibility for reaching agreement on any cross-cutting or common outcomes and objectives, and will support the development of discipline and program-specific outcomes. The IUSE Coordinating Committee will have a central role in proposing metrics that are appropriate for the IUSE framework. In addition, the REU Working Group will provide input to the Evaluation and Assessment Capability/EHR-based monitoring and evaluation planning in FY 2016. NSF's efforts to participate in the revision of the National Study of Postsecondary Faculty with the National Center for Education Statistics (via EHR and the National Center for Science and Engineering Statistics) will lead eventually to availability of data on teaching practices, the evolving role of technology in education, and the rapidly changing nature of faculty work which can inform approaches to professional development. Developing and implementing shared metrics across federal agencies will inform IUSE.

[23] www.ssireview.org/articles/entry/collective_impact

INCLUSION ACROSS THE NATION OF COMMUNITIES OF LEARNERS OF UNDERREPRESENTED DISCOVERERS IN ENGINEERING AND SCIENCE (NSF INCLUDES) $16,000,000 +$500,000 / 3.2%

Overview

NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science) is a comprehensive national initiative to enhance U.S. leadership in science and engineering discovery and innovation by proactively seeking and effectively developing science, technology, engineering, and mathematics (STEM) talent from all sectors and groups in our society. The NSF INCLUDES initiative will improve the preparation, increase the participation, and ensure the contributions of individuals from groups that traditionally have been underserved and/or underrepresented in the STEM enterprise. In particular, the specific goal of NSF INCLUDES is to develop the STEM talent of women, members of racial and ethnic groups that have been underrepresented in STEM, persons with low socio-economic status, and people with disabilities.

Diversity – of thought, perspective, and experience – is essential for excellence in research and innovation in 21st century science and engineering. Full participation of all of America's STEM talent is critical to the advancement of science and engineering for national security, health, and economic competitiveness. African Americans, Hispanics, Native Americans, women, persons with disabilities, and persons with low socio-economic status are underrepresented in various fields of science and engineering across all levels – from K-12 to undergraduate and graduate levels to long-term workforce participation. Inclusion of talent from all these sectors of American society is necessary for the health and vitality of the science and engineering community and its societal relevance. Some of the key challenges to this broad participation are: *under-preparation* and lack of opportunity for members of all demographic groups to become "STEM-capable"; *under-resourcing* as seen in growing disparities of access to quality learning and technology; and *under-production* of STEM graduates from abovementioned sectors. Significant investments, including those by NSF and the larger STEM community, have been made to address these long-standing problems. However, further investment is critical so that these challenges can be overcome and the U.S. science and engineering enterprise can benefit from the creative contributions by talented people from all sectors of society, yielding a competitive advantage in a globalized world for national security, health, and economy.

The NSF INCLUDES initiative will support two of NSF's Strategic Goals and associated objectives:
Goal 1: Transform the Frontiers of Science and Engineering – Objective 2: Integrate education and research to support the development of a diverse STEM workforce with cutting-edge capabilities; and
Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education – Objective 1: Strengthen the links between fundamental research and societal needs through investments and partnerships.

Total Funding for NSF INCLUDES

(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
-	**$15.50**	**$16.00**

Goals

The long-term goals of NSF INCLUDES are to fund new research, models, networks, and partnerships that lead to measureable progress at the national level, and the ability to scale the concepts of diversity and inclusion in STEM. This will be achieved, in part, by increasing coherence and leveraging synergies across the NSF broadening participation (BP) portfolio (see the Summary Table chapter for funding details), including both BP "focus" and BP "emphasis" programs, through alignment with the NSF INCLUDES framework. The multi-year goals are:

1. Synthesize and build the research base for broadening participation and foster the spread and adaptation of proven effective practices.
2. Support the identification and development of a set of shared goals and objectives developed by stakeholders, including those from specific STEM disciplines, whose attainment is essential for success in achieving inclusion in the Nation's scientific workforce and in high quality science learning opportunities.
3. Support local/regional and discipline-specific and crosscutting multi-stakeholder partnerships and networks (NSF INCLUDES Alliances) and support an NSF INCLUDES National Network.[1]

Building on activities started in fiscal years 2015 and 2016, in FY 2017 NSF will proceed to full implementation of NSF INCLUDES. The full implementation includes funding approximately five multi-year NSF INCLUDES Alliances as well as an NSF INCLUDES Backbone Organization, which will ensure that the Alliances work together and leverage each others' resources. The goals and objectives of the NSF INCLUDES Alliances will be catalogued to define the collective set of goals and objectives of the NSF INCLUDES National Network. Projects throughout the NSF BP portfolio will be engaged in supporting one or more of those objectives, using guidelines developed by the internal NSF Working Group for INCLUDES (WGI), and may affiliate in various ways with the NSF INCLUDES National Network. The NSF INCLUDES Backbone Organization will provide 1) a common system of tracking, reporting on national progress toward the goals and objectives; 2) systems for communicating across all entities involved in NSF INCLUDES; 3) ways of employing technology for scaling and sharing; 4) support for implementation research that will enable understanding and documentation of successful efforts as they are ongoing; and 5) technical assistance for managing evaluation and assessment, building effective strategies, developing networking opportunities for students, faculty, and other stakeholders.

The long-term impact of NSF INCLUDES will be continued U.S. leadership in discovery and innovation in science and engineering. This will be accomplished through the significant involvement of people from groups that have traditionally been underrepresented in all NSF-supported STEM fields.

Approach

A key tenet behind the NSF INCLUDES initiative is that achieving success will require much broader and more effective collaborations among all interested and important stakeholder communities and organizations concerned with STEM opportunities in K-12 education, community colleges, and universities. NSF will provide leadership in mobilizing concerned communities to partner with those stakeholders that may not routinely engage with NSF, e.g., community-based organizations, local education policy makers, foundations, not-for-profits, and industry. NSF INCLUDES will also leverage investments from other NSF programs and projects focused on broadening participation, building on lessons learned, best practices, and proven mechanisms for achieving success.

An NSF-funded INCLUDES National Network consisting of local/regional NSF INCLUDES Alliances and an NSF INCLUDES Backbone Organization will be created in FY 2017. NSF INCLUDES will catalyze and support networked activities to improve BP outcomes at national scale. For such collaborative networks to be successful at scale, it is essential that participating entities have common agendas, shared primary goals, shared measurement systems, and mutually reinforcing activities. The local/regional NSF INCLUDES Alliances will bring together key stakeholders to work collaboratively with a focused

[1] John Kania & Mark Kramer, "Collective Impact," *Stanford Social Innovation Review*, (Winter 2011), http://ssireview.org/articles/entry/collective_impact/; Kania and Kramer note that collective impact "requires a systematic approach to social impact that focuses on relationships between organizations and the progress toward shared objectives," p. 5.

commitment to achieve clearly defined, shared primary goals. Examples of potential primary goals that are national, but could be implemented regionally, include:

- All U.S. high schools offer Advanced Placement (AP)® courses in calculus, computer science, and physics by 2020.[2]
- All states allow engineering and/or computing courses to count toward high school graduation requirements by 2020.
- Over 75 percent of undergraduate students from underrepresented groups (URGs) have opportunities to participate in authentic STEM research experiences.
- In major urban centers, there are pre-K-20+ pathways, involving universities, community colleges, local schools, surrounding communities, not-for-profits, local businesses and industries, and science-rich institutions designed to enable success for students from URGs.
- In every NSF-supported discipline there is convergence on discipline-specific approaches to creating effective STEM pathways designed to draw in students from URGs by 2020.

An NSF-supported Backbone Organization will ensure that local and regional NSF INCLUDES Alliances collaborate among themselves. Therefore, the Backbone Organization will facilitate the creation of an NSF INCLUDES National Network that routinely communicates, shares data and knowledge, and leverages one another's best practices and strategies for success. The NSF INCLUDES National Network goals will align, shape, and inform NSF's wider BP investments at the directorate and program level.[3]

Investment Framework

NSF INCLUDES Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	-	$1.47	$1.40
CISE	-	1.87	1.78
EHR	-	3.00	4.00
ENG	-	1.47	1.40
GEO	-	2.57	2.44
MPS	-	2.74	2.60
SBE	-	0.50	0.50
IA	-	1.88	1.88
Total, NSF INCLUDES	**-**	**$15.50**	**$16.00**

Totals may not add due to rounding.

FY 2015 – FY 2016

Beginning in FY 2015, a series of forums and community events were held to shape the purposes and principles of NSF INCLUDES. During FY 2015, NSF leadership, in partnership with the scientific community, launched NSF INCLUDES with a Director's Workshop held in June.[4] The meeting focused on collective impact, a coordinated approach to scaling, and catalytic innovation. This event allowed community and academic leaders to identify critical levers to increase the impact of NSF INCLUDES, including the following key ideas:

[2] According to U.S. Department of Education Civil Rights data (see http://ocrdata.ed.gov), only 50 percent of high schools in the United States offer calculus and only 63 percent offer physics, with access for minority students considerably less than access for white students. Meanwhile, a new AP® Computer Science Principles (CSP) framework is being introduced in the 2016-2017 academic year, along with additional new computer science course offerings.

[3] John Kania & Mark Kramer, "Collective Impact," *Stanford Social Innovation Review*, (Winter 2011), www.ssireview.org/articles/entry/collective_impact/

[4] www.informalscience.org/sites/default/files/INCLUDES_Convening_Synthesis.Sep1.pdf

- Learn from and build on existing successes;
- Develop wide-ranging partnerships;
- Ensure shared measurements and systematic coordination and collaboration across the network; and
- Connect the research and practices of the science of broadening participation.

Following this event, NSF leadership engaged the community through discussions with NSF and directorate advisory groups (e.g., the Committee on Equal Opportunities in Science and Engineering (CEOSE), the Advisory Committees for Mathematical and Physical Sciences, Engineering, Education and Human Resources, etc.), national study groups (e.g., National Research Council (NRC), relevant White House initiative leaders, and other experts in broadening participation), and professional societies/associations. The purpose of this national dialogue was to identify key action areas, address discipline-specific needs and goals (e.g., shortages of women in computer science and some engineering fields), and highlight differences in attrition rates among under-represented groups by field and discipline. Leaders in projects currently funded in the NSF BP portfolio and other experts are being encouraged to engage and contribute to shaping the direction of NSF INCLUDES, as appropriate.

NSF INCLUDES Launch Pilots: In FY 2016, NSF is issuing a call for proposals to fund NSF INCLUDES Launch Pilots. NSF INCLUDES Launch Pilot projects will span two years of activity for a total of up to $350,000 each for 30 to 40 projects. Launch Pilot teams will be charged to develop plans for a collective impact approach to solving a key BP challenge that is of high interest to the members of the team. Teams might come together locally, regionally, nationally, or by disciplinary focus. Key to a successful proposal will be the identification of a specific goal, measurable objectives, and an argument that the right set of partners is being assembled, and possibly that disruptive innovation is intended. These planning and start-up activities are aimed at engaging with appropriate communities to test the feasibility of developing a full-scale plan and process for change, including identifying other support mechanisms for sustaining the efforts. In the second year, teams with successful planning activities are expected to carry out projects to demonstrate their ability to implement a collective impact approach to address the selected BP challenge.

NSF INCLUDES Backbone Organization Development: In FY 2016, a series of activities, including workshops and ideas labs, will identify the necessary components of the NSF INCLUDES Backbone Organization. The collective impact approach depends on strong measurement capability, communication, and mutually reinforcing activities. The NSF INCLUDES Backbone Organization development activity will bring clarity to the optimal NSF investments for FY 2017.

For both the NSF INCLUDES Launch Pilot and Backbone Organization development activities, NSF will use multiple approaches to notify and engage a wide array of organizations and stakeholders about the intentions and possibilities for NSF INCLUDES. A communication plan for NSF INCLUDES is under development, and it will incorporate social media and outreach components. For example, the many organizations and stakeholders who participated in the recent White House Summit on Next Generation High Schools[5] will be included in these outreach efforts.

<u>FY 2017 Request</u>

In FY 2017, the NSF INCLUDES investment will be $16.0 million. These funds will invest in the NSF INCLUDES Alliances, for an approximate total of $12.50 million, and the NSF INCLUDES Backbone Organization, for an approximate total of $3.50 million. NSF will issue a call for proposals to the NSF INCLUDES National Network in late FY 2016 for funding of awards in FY 2017. NSF anticipates two tracks in this call: one for NSF INCLUDES Backbone Organization activities, and one for NSF INCLUDES Alliances. NSF currently envisions funding about five NSF INCLUDES Alliances at approximately $2.50 million per year for each of five years.

[5] https://whitehouse.gov/sites/default/files/docs/fact_sheet-white_house_summit_on_next-generation_high_schools.pdf

Consistent with CEOSE's recommendations for a bold new initiative, NSF INCLUDES Alliances will leverage existing programs, people, organizations, alliances, and institutions to form NSF's next generation BP investments.[6] Each NSF INCLUDES Alliance will be committed to jointly solving a specific set of challenges. As mentioned above, in FY 2016, NSF INCLUDES Launch Pilot projects are expected to demonstrate how extant teams and organizations can be re-assembled and joined together to form new alliances with common goals and purposes, and collective impact-style approaches. Early in FY 2017, NSF INCLUDES Launch Pilot principal investigators (PIs) will share their goals and plans in a live event and webinar, enabling all to learn from their pilot project experiences. NSF INCLUDES Alliances will be funded late in FY 2017, enabling them to learn from and perhaps involve some of the most promising Launch Pilot activities. Some alliances might focus on emerging fields of science, such as data science, as key domains for advancing BP. The NSF INCLUDES Alliances will propose, implement, and assess solutions to address the seepage of talent from diverse communities and advance the talent among those who have been traditionally underrepresented in the STEM enterprise.

In addition to the NSF INCLUDES Alliances, the NSF INCLUDES Backbone Organization will be established in FY 2017 for a five-year award period. Based on the input received in FY 2016, the NSF INCLUDES Backbone Organization will facilitate the NSF INCLUDES collaborative activities. Among its many capabilities, the NSF INCLUDES Backbone Organization will demonstrate a capacity to communicate, assess, and measure progress toward goals; collect and monitor data; support implementation research; scale technological innovations; and provide technical expertise in collective impact. The NSF INCLUDES Backbone Organization will serve as a neutral third party within the NSF INCLUDES Network, working in close affiliation with the NSF INCLUDES Alliances.

Building on the activities of FY 2016, in FY 2017 the NSF INCLUDES effort will increasingly leverage the current and ongoing NSF BP portfolio through supplements to form linkages among the projects in the current portfolio, as well as with the new partnerships afforded by the NSF INCLUDES Alliance investments. For instance, discipline-specific programs can be more closely aligned with the goals of NSF INCLUDES through new solicitation language and Dear Colleague letters. The vision is that, over time, the full suite of NSF's focused, emphasis, and geographic BP programs become connected to and/or affiliated with the NSF INCLUDES activities and contribute to advancing the goals of the NSF INCLUDES Alliances while benefitting from the services of the NSF INCLUDES Backbone Organization.

NSF will continue to leverage activities of the National Science and Technology Council (NSTC) Committee on STEM Education to build on existing interagency collaborations and create new partnerships as needed to support the NSF INCLUDES goals. As co-chair to the Federal Coordination in STEM Education Task Force (FC-STEM) BP Interagency Working Group (IWG), where broadening participation is critical to the success of all of the FC-STEM IWGs, NSF will present NSF INCLUDES as an opportunity for collaboration that helps meet the goals of the Co-STEM Strategic Plan.[7]

FY 2018 – FY 2021

- NSF will continue to advocate for and invest in education, mentoring, and research to create STEM experiences that empower every segment of the American population to succeed regardless of demographic characteristics.
- Building on the activities of FY 2016 and 2017, the NSF INCLUDES effort will increasingly leverage the ongoing NSF BP portfolio.

[6] CEOSE, 2011 - 2012 Biennial Report to Congress. (www.nsf.gov/od/oia/activities/ceose/reports/Full_2011-2012_CEOSE_Report_to_Congress_Final_03-04-2014.pdf)
[7] www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

NSF INCLUDES will capitalize on NSF's role in basic research across all fields of science and engineering and across all levels and venues of STEM education. The ongoing activities in FY 2018 and beyond include supporting innovative projects to achieve new levels of partnerships at a national scale. New knowledge will continue to inform more systematic and strategic broadening participation efforts. The NSF Evaluation and Assessment Capability will be engaged in the oversight responsibilities for assessing and evaluating the NSF INCLUDES portfolio, including a three-year review to determine next steps. NSF plans to continue the convening of stakeholders to maintain the national momentum for diversifying the STEM enterprise and disseminate promising/best practices.

Evaluation Framework

To be successful, NSF INCLUDES must be systemic, have impact at scale, and be sustainable. Key to this broader impact of the initiative is an evidence-based approach that drives management decision-making, mid-course corrections, improvements, sharing of information, and enhancements for yields greater than incremental progress. NSF evaluation experts, in concert with NSF INCLUDES Backbone Organization's experts, will develop and refine the evaluation and monitoring framework for each of the major goals, including annual metrics and ambitious short- and long-term targets (three-year and five or more years, respectively) for program evaluation. In FY 2016, a feasibility assessment will begin with data collection and evaluation targeted for FY 2017.

Evaluation will be driven by a focus on the collective goals and on the design of indicators and measures for tracking collective progress toward achieving them, including the development of:

- Baseline data assembled for the collective objectives of the FY 2016 NSF INCLUDES Launch Pilots; and
- Common outcomes and metrics for NSF INCLUDES investments in collaboration with PIs, and the NSF INCLUDES Backbone Organization will be reviewed annually.

As part of the management and evaluation of NSF INCLUDES, NSF will:

- Develop and implement an NSF INCLUDES social media and communications strategy;
- Determine and implement appropriate approaches to monitoring system(s) designed for NSF INCLUDES investments and pilots;
- Collect data and report progress toward NSF INCLUDES collective objectives; and
- Plan for post-program activity with a report of recommendations for future NSF BP directions (FY 2021).

NSF INCLUDES provides the opportunity to implement a coordinated approach for evaluating ongoing efforts across NSF's efforts in broadening participation. NSF anticipates using a portfolio approach and innovative text-mining tools for portfolio analysis. Results from the NSF INCLUDES evaluation activities will help strengthen, improve, or refine ongoing programs. This investment priority will be closely monitored for its successes in breaking new ground in both assessment practices and innovative solutions for addressing the underrepresentation challenge in STEM.

MAJOR INVESTMENTS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) GRADUATE STUDENTS AND GRADUATE EDUCATION

Overview

A U.S. science, technology, engineering, and mathematics (STEM) workforce with advanced preparation in research and innovation, and in professional fields such as cybersecurity and STEM teaching, is essential for the progress of science and engineering. NSF's commitment to advancing STEM and developing human capital in tandem has been a hallmark of its investments since its founding in 1950. Today, emerging fields of science and engineering increasingly demand team efforts across institutions and national boundaries and rest on the use of sophisticated data infrastructure, instruments, and networks of researchers. Interdisciplinary approaches are needed to solve complex problems and fuel the production of scientific advances. The growth of computationally intensive and data-enabled science is dramatically changing the knowledge and experience required of researchers and other STEM professionals across fields. Thus, the preparation of graduate students in STEM must continue to evolve in order to provide a supply of scientists and engineers who not only meet the needs of the STEM enterprise, but who have the knowledge, skills, and preparation to advance it and lead innovation in academia, the private sector, and government.

Investing in discoverers – that is, building through inclusive processes a diverse and talented next generation of STEM research leaders and professionals across sectors – is an important NSF investment focus. A major portion of NSF's overall investment in graduate education and graduate students supports research assistants funded through research grants. In addition, NSF directorates have instituted several other approaches to supporting graduate students, ranging from dissertation completion awards, to scholarships for professional preparation in particular fields, to traineeship and fellowship mechanisms that advance the progress of science and engineering for the Nation.

NSF is active in government-wide coordination of graduate education, with an NSF representative serving as the co-chair of the Federal Coordination of STEM (FC-STEM) Interagency Working Group on Graduate Education, in partnership with a colleague from the National Institutes of Health. Through this group, NSF works to collaborate on activities, promote innovation, and disseminate effective models of graduate education practice and support across the FC-STEM agencies for the benefit of the graduate students in science and engineering.

NSF is developing an NSF strategic framework for graduate education that will be released in spring of 2016. In FY 2017, it will guide the review, renewal, and development of solicitations for fellowship and traineeship programs, promote effective collaboration across the NSF directorates, and enhance professional development opportunities for graduate students.

NSF also has established an Agency Priority Goal (APG) for FY 2016 and FY 2017 on improving graduate student preparedness: "Improve STEM graduate student preparedness for entering the workforce: By September 30, 2017, NSF will fund at least three summer institutes and 75 supplements to existing awards to provide STEM doctoral students with opportunities to expand their knowledge and skills to prepare for a range of careers." The implementation of the APG will be integrated with the implementation of the strategic framework for graduate education.

Goal
The goal of NSF's collective investments in STEM graduate education and STEM graduate students is to prepare a diverse workforce with advanced research training that is equipped to transform the frontiers of science and engineering, and to prepare professionals, through various levels and approaches to graduate education, to participate and innovate in STEM intensive careers in ongoing and emerging areas.

NSF's graduate STEM investments will:
- Support training in areas of national science and engineering priorities.
- Catalyze development of innovative models for graduate education with potential for scalability.
- Build the research knowledge base to inform improvements in graduate education.
- Promote professional development of graduate students for both academic and non-academic careers.

Approach
NSF's two major agency-wide programs in graduate education are the Graduate Research Fellowship Program (GRFP) and the NSF Research Traineeship (NRT) program. The Directorate for Education and Human Resources (EHR) has administrative leadership responsibility for both programs. Management of these programs is guided by NSF-wide working groups. Both programs contain design elements recommended in major national reports[1] as ways to better prepare graduates for a broad range of careers. GRFP has identified and supported future outstanding basic STEM researchers since 1952. The program also provides opportunities for graduate students to gain research experience internationally and in federal agencies. GRFP provides rich data that will be used for monitoring career outcomes longitudinally and will contribute to improving the understanding of STEM professional workforce development.

There are several other programs at NSF that focus on the development of sectors of the STEM workforce, and integrate support to students with the development and testing of new models and approaches to graduate education. For example, the CyberCorps®: Scholarship for Service (SFS) program, led by EHR, addresses government's need for a cybersecurity workforce as authorized by the Cybersecurity Enhancement Act of 2014. In addition to scholarships for undergraduate and graduate students, the program supports the expansion of existing educational opportunities and resources in cybersecurity through research on the teaching and learning of cybersecurity. Collaborators include the NSF Directorate for Computer and Information Science and Engineering (CISE), the U.S. Department of Homeland Security, and the Office of Personnel Management. The Robert Noyce Teacher Scholarship program (Noyce) provides fellowship support to master teachers at the graduate level and funds innovation and development in STEM teacher education approaches. East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI) provides international research experiences for U.S. graduate students.

In addition to GRFP, NRT, SFS, Noyce, and EAPSI, the Alliances for Graduate Education and the Professoriate (AGEP), Louis Stokes Alliances for Minority Participation's Bridge to the Doctorate (LSAMP-BD) track, and NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) support the successful entry and transition of underrepresented and underserved populations into STEM graduate education and into the STEM workforce. Taken together, this broad suite of programs contributes substantially to the NSF investment in graduate education of the STEM research and education workforce of the future.

In FY 2017, all R&RA directorates, the Office of International Science and Engineering, and the Office of

[1] American Chemical Society Presidential Commission (2012). *Advancing graduate education in the chemical sciences*. American Chemical Society, Washington, DC. Retrieved from www.acs.org/content/dam/acsorg/about/governance/acs-presidential-graduate-education-commission-full-report.pdf; Biomedical Research Workforce Working Group (2012) Biomedical Research Workforce Working Group Draft Report. National Institutes of Health, Bethesda Retrieved from http://acd.od.nih.gov/bmw_report.pdf

Integrative Activities are engaged in considering how to extend the range of professional development opportunities for graduate students in the various disciplines served by NSF and are undertaking several pilot activities. In FY 2017, the Division of Graduate Education (DGE) in EHR will extend opportunities for international research experiences, through Graduate Opportunities Worldwide (GROW), and internship opportunities, through Graduate Research Internship Program (GRIP), to graduate students in other EHR programs such as the Noyce, LSAMP, and S-STEM programs. EHR is pursuing collaborations with other directorates to establish additional partnerships with industry for internship opportunities to give graduate students the professional development needed to pursue successful careers in STEM and STEM-related occupations.

Finally, in FY 2017, the DGE component of EHR's core research program will emphasize research on the development of the STEM workforce.

Investment Framework

<u>Graduate Research Fellowship Program (GRFP)</u>

The goal of GRFP is to help build the U.S. STEM human capital necessary to ensure the Nation's leadership in advancing innovations in science and engineering. GRFP selects, recognizes, and financially supports graduate students with demonstrated high potential for excellence in STEM and in their chosen careers. Applications are welcome from students in all STEM disciplines supported by NSF and in STEM interdisciplinary areas, including STEM education. Fellows have opportunities for international research through Graduate Opportunities Worldwide (GROW) and federal internships through Graduate Research Internship Program (GRIP).

GRFP noteworthy activities are as follows:

- Program innovation has focused on professional development initiatives such as GROW and GRIP. The plans for evaluating GROW will begin in FY 2016, and the plans for evaluating GRIP will begin in FY 2017.
- In 2014, the review of GRFP applications transitioned to a completely online review of the entire application pool supported by virtual panels. In FY 2015, over 16,000 applications were reviewed by over 1,500 reviewers in 47 virtual panels. The online review and virtual panels expanded the ability of the community to participate in the review process.
- The pilot survey and initial data collection for monitoring career outcomes of GRFP recipients longitudinally began in the first quarter of FY 2016. This activity is conducted in partnership among the EHR Evaluation Team, the NSF Evaluation and Assessment Capability, and the National Center for Science and Engineering Statistics. This team will develop and pilot a GRFP survey instrument and process that may be used as an ongoing longitudinal monitoring system to assess program outcomes.
- EHR will conduct outreach to undergraduate institutions and encourage undergraduates to apply to GRFP. In FY 2017, the agency will continue initiatives begun in FY 2014 to enhance the capacity of minority-serving institutions to increase the number of students who successfully compete for GRFP awards. The GRFP and LSAMP programs have designed outreach activities to LSAMP institutions with significant cohorts of STEM students who are enrolled in or preparing for graduate training. In FY 2017, further work with LSAMP-BD institutions will continue.
- DGE will pilot activities in FY 2017 that promote professional development opportunities that prepare graduate students for careers in industry.
- In 2017, GRFP will continue to partner with the Experimental Program to Stimulate Competitive Research (EPSCoR) to provide outreach to students and faculty in EPSCoR states, with a special focus on minority-serving institutions located in EPSCoR jurisdictions.

GRFP Funding by Account

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Education and Human Resources	$166.52	$165.96	$166.08
Research and Related Activities	166.72	165.96	166.08
Total GFRP	**$333.24**	**$331.92**	**$332.16**
Number of New Fellows	2,000	2,000	2,000
Projected Fellows on Tenure[1]	5,927	6,000	6,000

Totals may not add due to rounding.

[1] Fellowship tenure status is the period of time during which fellows actively utilize the fellowship award to pursue an advanced degree in a STEM field.

NSF Research Traineeship (NRT)

The goals of NRT are to support highly effective training of STEM graduate students in interdisciplinary research areas of national priority as well as to create and promote new, innovative, effective, and scalable models for STEM graduate student training. The NRT program is distinguished from prior traineeship programs by its emphasis on training for multiple career pathways, rotating priority research themes, inclusion of both masters and doctoral students, a broader definition of trainees, and greater budgetary and programmatic flexibility. In FY 2015, the scope of the NRT program was expanded to add the Innovation in Graduate Education (IGE) Track. The IGE track is dedicated to piloting, testing, and evaluating novel, innovative, and potentially transformative approaches to graduate education, both disciplinary and interdisciplinary, to generate the knowledge required for their customization, implementation, and broader adoption. In FY 2017, IGE is supported at a level of $7.0 million.

NRT funds proposals to test, develop, and implement innovative and effective STEM graduate education models, to promote interdisciplinary and broad professional training of graduate students, and to foster fundamental research advances in support of national priorities. NRT thus provides a mechanism for developing a knowledge base about the implementation and impact of innovative graduate traineeship programs and graduate education policies. In FY 2017, NRT will support new STEM graduate education pilots and models in order to transform current practices in graduate education.

In FY 2017, the NRT traineeship track will continue to solicit proposals in the NSF-wide priority research areas of Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) and Understanding the Brain (UtB). Specifically, at the FY 2017 Request level, EHR will invest $2.0 million to seek proposals that support a virtual resource platform for a graduate student network. Investigator-initiated interdisciplinary-themed proposals outside the priority research themes will continue to be accepted. In FY 2017, EHR will pilot a program that will enable NRT trainees to participate in federal internships in partnerships with GRIP.

NRT Funding by Directorate[1]
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$3.24	$2.33	$2.82
Computer and Information Science and Engineering	13.38	6.69	7.10
Education and Human Resources[2]	40.74	31.05	37.71
Engineering	2.85	2.59	2.50
Geosciences	6.63	4.43	3.32
Mathematical and Physical Sciences	5.04	4.47	4.54
Social, Behavioral, and Economic Sciences	2.52	2.59	0.64
Total	**$74.40**	**$54.15**	**$58.63**

Totals may not add due to rounding.

[1] Outyear commitments to the Integrative Graduate Education and Research Traineeship program are included in the NRT amounts and total $12.97 million in FY 2015 and $6.35 million in FY 2016.

[2] EHR's NRT funding includes $7.0 million for Innovation in Graduate Education (IGE) as a track within the NRT program.

CyberCorps®: Scholarship for Service (SFS)

The SFS program addresses cybersecurity education and workforce development through scholarships and building institutional capacity. The Scholarship Track provides funding to institutions for awarding scholarships to undergraduate and graduate students in cybersecurity. The goal of the Capacity Track is to increase the ability of the United States higher education enterprise to effectively produce cybersecurity professionals. Of the total SFS budget, approximately half supports graduate program activities. In return for their scholarships, tuition, fees, health insurance, travel, and book allowances, recipients work after graduation for a federal, state, local, or tribal government organization in a position related to cybersecurity for a period equal to the length of the scholarship.

In FY 2017, SFS will support laying the groundwork for SFS alumni to serve as a national resource over the course of their careers.

FY 2017 activities will include increasing the number of Research Experiences for Undergraduates (REU) Sites focused on cybersecurity emphasizing experience for first- and second-year undergraduate students, especially veterans, and perhaps ultimately enabling more students to enter cybersecurity fields at the graduate level.

CyberCorps®: Scholarship for Service (SFS)
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
SFS	$45.04	$50.00	$70.00

Additional Programs Supporting STEM Graduate Education and Workforce Development

Alliances for Graduate Education and the Professoriate (AGEP)

The AGEP program is committed to the national priority of increasing the numbers of underrepresented minorities, including those with disabilities, entering and completing STEM graduate education and postdoctoral training to levels representative of the available pool.

East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI)

The EAPSI program contributes to the development of a globally engaged U.S. science and engineering workforce by providing international research experiences for U.S. graduate students in the dynamic East Asia and Pacific region. EAPSI is a partnership with funding agencies in Australia, China, Japan, Korea, New Zealand, Singapore, and Taiwan. The program provides individually tailored summer research opportunities in leading labs and research sites around the region, allowing U.S. graduate students to benefit from world class expertise and leverage investments in cutting edge research in partner countries. EAPSI provides fellowships to more than 200 graduate students per year.

Louis Stokes Alliances for Minority Participation-Bridge to the Doctorate (LSAMP-BD)

The LSAMP program assists universities and colleges in diversifying the STEM workforce through their efforts at significantly increasing the number of students successfully completing high quality degree programs in STEM disciplines. Particular emphasis is placed on transforming STEM education through innovative recruitment and retention strategies and experiences in support of groups historically under-represented in STEM disciplines: African-Americans, Alaskan Natives, American Indians, Hispanic Americans, Native Hawaiians, and Native Pacific Islanders.

Established LSAMP alliances are eligible to apply for Bridge to the Doctorate support. LSAMP-BD funding allows institutions to provide stipend support ($32,000/year) along with cost of education allowance to the institution for tuition, health insurance, and other normal fees up to $10,500 per year for up to two years of post-baccalaureate study. A plan for formally connecting a significant number of newly matriculated LSAMP students, including master's degree graduates, to doctoral degree programs is expected. LSAMP-BD projects are encouraged to partner with other NSF-funded programs, such as Centers of Research Excellence in Science and Technology (CREST), NSF research centers, NRT, or AGEP. In FY 2017, LSAMP-BD will continue to collaborate with GRFP on effective approaches to increase the diversity of the GRFP applicant pool.

NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)

The S-STEM program was established by NSF in accordance with the American Competitiveness and Workforce Improvement Act of 1998 (P.L. 105-277) as modified by P.L. 106-313 and P.L. 108-447 in 2004. The Act reflects the national need to increase substantially the number of American scientists and engineers. In addition to the long-standing scholarship support, S-STEM projects contribute to the knowledge base of research in education by carrying out research on factors such as recruitment and retention of STEM students. S-STEM is funded through H1B Nonimmigrant Petitioner Account receipts. See the H-1B Nonimmigrant Petitioner Fees section in the EHR chapter for more information.

The S-STEM program provides institutions with funds for student scholarships to encourage and enable academically talented U.S. students demonstrating financial need to enter the STEM workforce or STEM graduate school following completion of an associate, baccalaureate, or graduate degree in STEM fields. The program emphasizes the importance of recruiting students to STEM disciplines, mentoring and supporting students through degree completion, and partnering with employers to facilitate student career placement in the STEM workforce. S-STEM provides individual scholarships of up to $10,000 per year, depending on financial need.

Robert Noyce Teacher Scholarship (Noyce)
The Noyce program seeks to encourage talented STEM majors and professionals to become K-12 mathematics and science teachers. Through the Noyce NSF Teaching Fellowship/Master Teaching Fellowship Track, funding is provided to support STEM professionals who enroll as NSF Teaching fellows in master's degree programs leading to teacher certification by providing academic courses, professional development, and salary supplements while they are fulfilling a four-year teaching commitment in a high-need school district. This track also supports the development of NSF Master Teaching fellows by providing professional development and salary supplements for exemplary mathematics and science teachers to become Master Teachers while they fulfill a five-year teaching commitment in high-need school districts.

Additional Programs Supporting STEM Graduate Education and Workforce Development

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
AGEP	$8.00	$8.00	$8.00
EAPSI	1.33	1.80	2.50
LSAMP-BD	17.00	17.00	17.00
S-STEM	0.30	0.30	0.30
Noyce Teaching and Master Teaching Fellows (10A)	22.22	22.00	22.00
Total	**$48.85**	**$49.10**	**$49.80**

Totals may not add due to rounding.

Evaluation Framework

The framework to assess the impact of the NSF-wide investment in graduate education will be developed in FY 2016 and FY 2017. Because the impact of graduate education investments develops over time, the assessment framework will include both immediate and longitudinal metrics that measure outcomes in a hierarchical fashion. Metrics may include indicators on participation in NSF programs, participant and faculty feedback, and evaluation of STEM education in regard to learning and learning environments, workforce development, and broadening participation. Indicators also may include impact on career outcomes. The metrics will be benchmarked to national indicators, to the extent possible; similar metrics will be used across programs to enable measurement of thematic investments. Evaluation plans will be coordinated with NSF's Evaluation Assessment Capability unit and the National Center for Science and Engineering Statistics.

NATIONAL SCIENCE FOUNDATION CENTERS

NSF supports a variety of centers programs that contribute to the Foundation's mission and vision. Centers exploit opportunities in science, engineering, and technology in which the complexity of the research program or the resources needed to solve the problem require the advantages of scope, scale, duration, equipment, facilities, and students. Centers are a principal means by which NSF fosters interdisciplinary research.

NSF Centers
(Dollars in Millions)

	Program Initiation	Number of Centers in FY 2015[1]	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Centers for Analysis & Synthesis	1995	4	$21.00	$18.60	$16.00	-$2.60	-14.0%
Centers for Chemical Innovation	1998	11	36.66	28.10	29.50	1.40	5.0%
Engineering Research Centers	1985	22	59.69	56.50	61.00	4.50	8.0%
Materials Centers[2]	1994	24	79.66	56.00	56.00	-	-
Nanoscale Science & Engineering Centers	2001	6	11.73	7.71	6.71	-1.00	-13.0%
Science & Technology Centers	1987	14	50.84	59.99	60.10	0.11	0.2%
Science of Learning Centers[3]	2003	3	8.46	-	-	-	N/A
Totals		**84**	**$268.04**	**$226.90**	**$229.31**	**$2.41**	**1.1%**

Totals may not add due to rounding.

[1] Includes centers that received no-cost award extensions in FY 2015 but no additional funding.

[2] Due to delayed awards processing, funding for FY 2015 includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

[3] The Science of Learning Centers program ended as planned in FY 2015 when the last centers reached the end of their ten-year funding cycles.

Description of Major Changes

Centers for Analysis and Synthesis – BIO
The FY 2017 Request of $16.0 million, $2.60 million below the FY 2016 Estimate, will fund three Centers for Analysis and Synthesis. These centers are described below.

In FY 2017, funding for the Plant Science Cyberinfrastructure Collaborative (iPlant) is reduced $2.0 million below the FY 2016 Estimate to $7.0 million. This reduction is part of this center's planned ramp-down as FY 2017 is the final year of its ten years of support. iPlant is led by scientists at the University of Arizona, the Texas Advanced Computing Center, Cold Spring Harbor Laboratory, and University of North Carolina at Wilmington. It enables new conceptual advances through integrative, computational thinking to address an evolving array of grand challenges in the plant sciences, including innovative approaches to education, outreach, and the study of social networks.

NSF FY 2017 support to the University of Tennessee Knoxville for the National Institute for Mathematical and Biological Synthesis (NIMBioS) is $3.0 million, $600,000 below the FY 2016 Estimate. This includes $200,000 from the Directorate for Mathematical and Physical Sciences (MPS) Division of Mathematical Sciences (DMS). The decrease is part of the planned ramp-down of the center as FY 2017 is the final year of support. At NIMBioS, top researchers from around the world collaborate across disciplinary boundaries to find creative solutions to today's complex biological problems. The education and outreach program

focuses on the interface between mathematics and biology and promotes cross-disciplinary approaches to science for learners of all ages.
The FY 2017 Request for the National Socio-Environmental Synthesis Center (SESync) is $6.0 million, equal to the FY 2016 Estimate. This center will undergo a renewal review in FY 2016, so FY 2017 support is contingent upon a successful review. This Center uses synthetic approaches to advance the frontiers of scientific understanding of environmental complexity to anticipate and manage emerging environmental change.

Centers for Chemical Innovation (CCI) – MPS

The CCI program is designed to address major, long-term fundamental chemical research challenges attracting broad scientific and public interest, as well as to provide a rich environment for education, outreach, and innovation. The CCIs deliver career-shaping educational opportunities for undergraduate and graduate students and for postdoctoral researchers, including collaborative research and mentoring, cross-disciplinary training, international research experiences, entrepreneurial and innovation training, and communication training.

The program is currently structured as a two-phase competition. Phase I centers are funded for three years and may compete for larger Phase II awards, which are funded for five years with potential for renewal for up to ten years.

In FY 2017, CCI program funding (+$1.40 million, to a total of $29.50 million) is expected to support nine Phase II centers and up to three Phase I awards selected in a new competition planned for FY 2017. Total funding required for these centers is $41.40 million, depending on final number of awards made. Of this total, $29.50 million is provided in this request. The remaining amount is expected to be provided via forward funding from prior fiscal years, co-funding by the MPS Office of Multidisciplinary Activities, and support from the National Aeronautics and Space Administration (NASA) through an ongoing interagency agreement.

In FY 2017, the Center for Enabling New Technologies through Catalysis (CENTC) will sunset, the Center for Selective C-H Functionalization (CCHF) will be in its 5th year and under consideration for renewal, and the other seven centers will continue in Phase II. An external program evaluation for the CCI program is expected to begin in FY 2017 and completed by FY 2019.

Engineering Research Centers (ERC) – ENG

NSF's ERCs enable innovation, bridging the energy and intellectual curiosity of university research focused on discovery with real-world engineered systems and technology opportunities through partnerships with industry. These centers also are successful in educating a technology-enabled workforce with hands-on real-world experience. ERCs can be funded for up to ten years if they clear two renewal reviews, one in year-three to determine if they are structured effectively to deliver on program goals, and another in year-six to determine if they are delivering effectively, making an impact, and tackling challenging tasks to warrant further support.

The ERC program periodically commissions program-level evaluations by external evaluators to determine the effectiveness of ERC graduates in industry, the benefits of ERC membership to industry and others. In FY 2015, NSF funded the National Academy of Engineering (NAE) in collaboration with the National Research Council (NRC) to study "The Future of Center-Based, Multidisciplinary Engineering Research." This topic arises from discussions NAE held with the NRC on the future of NSF's center-based, multidisciplinary engineering research. The project includes a 21-month study that will articulate a new vision for NSF's center-based research over the next two decades, identify needs and gaps in current approaches, and provide guiding principles and possible strategies for implementing the new vision. A report is expected in FY 2017.

At the FY 2017 Request level, 18 ERCs will be funded at $61.0 million ($4.50 million above the FY 2016 Estimate). ENG will award the next class of four ERCs in FY 2017, which requires an increased investment to support planned growth of the Class of 2015 centers and increased first year support of the Class of 2017 ERCs. First year support will increase from the traditional funding profile of $3.25 million per center to $3.50 million per center. Funding and numbers of centers include four Nanoscale ERCs, three from the class of FY 2012 and one from the class of FY 2015.

Materials Centers – MPS

Materials Research Science and Engineering Centers (MRSEC) advance materials research and provide students with an interdisciplinary education, including global experiences. These centers address fundamental research problems of intellectual and strategic importance that will advance U.S. competitiveness and the development of new technologies.

The MRSEC program continues to support the Materials Research Facilities Network (MRFN), which links the instrumentation and subject matter expertise of MRSECs to the larger materials community as well as encourages MRSEC-to-MRSEC collaborations. The MRSEC program also continues to support the interaction of MRSEC Education Coordinators with the NSF Directorate for Education and Human Resources/Division of Research on Learning in Formal and Informal Settings (EHR/DRL) to formulate methodologies for standardizing outreach program assessment and evaluation.

Finally, MRSECs interact with minority serving institutions through the Partnership for Research and Education in Materials (PREM) program. Currently, there are 12 active PREM awards at NSF, all of which are connected to MRSECs. MRSECs are encouraged to develop initiatives and/or educational programs to broaden participation.

The FY 2017 Request at $56.0 million (no change from the FY 2016 Estimate) will support approximately 20 MRSECs, with the actual number depending on the outcome of the next MRSEC competition. MRSEC competitions are held every three years. Twelve centers were awarded as the result of the latest completion in FY 2014. In the next MRSEC competition in FY 2017, nine current centers are expected to re-compete along with about 80 new applicants. Awards are typically $1.60 million to $3.60 million per year, depending on the number of interdisciplinary research groups in a center.

Nanoscale Science and Engineering Centers (NSEC) – multi-directorate

Nanotechnology research, which addresses the smallest of scales, is projected to be one of the largest drivers of technological innovation for the next decade and beyond. This potential was recognized in the National Nanotechnology Initiative, particularly in the burgeoning area of nanomanufacturing. Research at the nanoscale aims to advance the development of the ultra-small technology that will transform electronics, materials, medicine, environmental science, and many other fields.

At the FY 2017 Request Level, $6.71 million ($1.0 million below the FY 2016 Estimate) NSF will fund two sunsetting NSECs. This will be the final year of support as the NSEC program ends as planned. Support for nanotechnology-related projects will continue in other programs, such as the Nanosystems Engineering Research Centers within the Engineering Research Centers (ERC) and the Materials Science and Engineering Centers (MRSEC), both of which are described above.

Science and Technology Centers: Integrative Partnerships (STCs) - multi-directorate
The Science and Technology Centers: Integrative Partnerships (STC) program advances interdisciplinary discovery and innovation in science and engineering through the integration of cutting-edge research, excellence in education, targeted knowledge transfer, and the development of a diverse workforce. The STC portfolio reflects NSF-supported disciplines. Examples of investments include: understanding the brain; engineering of biological systems; energy-efficient electronics; global and regional environmental systems − sustainability and change; new ways of handling the extraction, manipulation, and exchange of information; and new materials for optical and electronic applications. STCs engage the Nation’s intellectual talent and collaborate with partners in academia, industry, national laboratories, and government. STCs strengthen the caliber of the Nation’s science, technology, engineering, and mathematics (STEM) workforce through intellectually challenging research experiences for students, postdoctoral fellows, researchers, and educators and advance public scientific understanding through partnerships with K-12 and informal education communities.

The FY 2017 Request of $60.10 million ($110,000 over FY 2016 Estimate) will support twelve STCs and the administrative costs ($900,000) associated with management and oversight of the program. All are continuing awards from the FY 2010, FY 2013, and FY 2016 cohorts. Awards are for five years, with possible renewal for an additional five years, or 10 years total. Award sizes are typically $4.0 million to $5.0 million per year.

Estimates for Centers Participation in 2015

	Number of Participating Institutions	Number of Partners	Total FY 2015 NSF Support (in millions)	Total Leveraged Support (in millions)	Number of Participants
Centers for Analysis & Synthesis	1,910	933	$21	$0	12,680
Centers for Chemical Innovation	86	84	$37	$8	899
Engineering Research Centers	836	385	$60	$134	4,771
Materials Centers[1]	400	296	$80	$49	4,500
Nanoscale Science & Engineering Centers	450	350	$12	$25	4,300
Science & Technology Centers	106	105	$51	$44	905
Science of Learning Centers	203	252	$8	$42	2,162

[1] Due to delayed awards processing, funding includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

No. of Participating Institutions: All academic institutions participating in activities at the centers.

No. of Partners: The total number of non-academic participants, including industry, states, and other federal agencies at the centers.

Total Leveraged Support: Funding for centers from sources other than NSF.

Number of Participants: The total number of people who use center facilities, not just persons directly support by NSF.

Centers Supported by NSF in FY 2015

Center	Institution	State
Centers for Analysis and Synthesis		
National Evolutionary Synthesis Center[1]	Duke, NC State U, U of N. Carolina	NC
National Institute for Mathematical & Biological Synthesis	U of Tennessee	TN
Plant Science Cyberinfrastructure Collaborative	U of Arizona	AZ
Socio-Environmental Synthesis Center	U of Maryland	MD
Centers for Chemical Innovation		
Center for Aerosol Impacts on Climate and Environment (phase II)	U of California-San Diego	CA
Center for Chemical Evolution (phase II)	Georgia Institute of Tech	GA
Center for Enabling New Technologies through Catalysis (phase II)	U of Washington	WA
Center for Multiscale Theory and Simulation (phase I)[1]	U of Chicago	IL
Center for Selective C-H Functionalization (phase II)	Emory	GA
Center for Sustainable Materials Chemistry (phase II)	Oregon State	OH
Center for Sustainable Nanotechnology (phase II)	U of Wisconsin	WI
Center for Sustainable Polymers (phase II)	U of Minnesota-Twin Cities	MN
Center for Sustainable Renewable Feedstocks (phase I)	U of California-Santa Barbara	CA
Chemistry at the Space-Time Limit (phase II)	U of California-Irvine	CA
CO^2 as a Sustainable Feedstock for Chemical Commodities (phase I)	Brown	RI
Solar Fuels (phase II)	California Institute of Tech	CA
Engineering Research Centers		
Advanced Self-Powered Systems of Integrated Sensors and Technologies	North Carolina State U	NC
Bio-mediated and Bio-inspired Geotechnics (CBBG)	Arizona State U	AZ
Biomimetic Microelectronic Systems[1]	U of Southern California	CA
Biorenewable Chemicals	Iowa State	IA
Center for Ultra-wide-area Resilient Electric Energy Transmission Network (CURENT)	U of Tennessee	TN
Collaborative Adaptive Sensing of the Atmosphere	U of Massachusetts-Amherst	MA
Compact and Efficient Fluid Power	U of Minnesota	MN
Future Renewable Electric Energy Delivery and Management Systems	North Carolina State	NC
Integrated Access Networks	U of Arizona	AZ
Mid-Infrared Technologies for Health and the Environment	Princeton	NJ
Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies	University of Texas-Austin	TX
Nanotechnology Enabled-Water Treatment Systems (NEWT)	Rice University	TX
Optimization for Electro-thermal Systems (POETS)	U of Illinois-Urbana Champaign	IL
Quality of Life Technology[1]	Carnegie Mellon/U of Pittsburgh	PA
Quantum Energy and Sustainable Solar Technologies (QESST)	Arizona State	AZ
Re-inventing the Nation's Urban Water Infrastructure	Stanford	CA
Revolutionizing Metallic Biomaterials	North Carolina A&T U	NC
Sensorimotor Neural Engineering	U of Washington	WA
Smart Lighting	Rensselaer Polytechnic Institute	NY
Structured Organic Particulate Systems	Rutgers	NJ
Synthetic Biology	U of California-Berkeley	CA
Translational Applications of Nanoscale Multiferroic Systems	U of California-Los Angeles	CA
Materials Centers		
Brandeis Materials Research Science and Engineering Center	Brandeis	MA
Center for Emergent Materials	Ohio State	OH
Center for Multifunctional Nanoscale Materials Structures	Northwestern	IL
Center for Nanoscale Science	Pennsylvania State	PA

[1] These centers received no-cost award extensions in FY 2015 but no additional funding.

Center for Nanostructured Interfaces	U of Wisconsin	WI
Center for Photonics and Multiscale Nanomaterials	U of Michigan	MI
Center for Plasmonics and Organic Spintronics	U of Utah	UT
Center for Polarization and Spin Phenomena in Nanoferroic Structures	U of Nebraska	NE
Center for Research on Interface Structures and Phenomena	Yale	CT
Chicago Materials Research Centers	U of Chicago	IL
Columbia Center for Precision Assembly of Solids	Columbia	NY
Cornell Center for Materials Research	Cornell	NY
Harvard Materials Research Science and Engineering Center	Harvard	MA
Laboratory for Research on the Structure of Matter	U of Pennsylvania	PA
Materials Research Laboratory at UCSB	U of California-Santa Barbara	CA
Materials Research Science and Engineering Center	Georgia Institute of Tech	GA
Materials Research Science and Engineering Center	U of Minnesota	MN
Materials Research Science and Engineering Center on Polymers	U of Massachusetts-Amherst	MA
MIT Center for Materials Science and Engineering	Massachusetts Institute of Tech	MA
NYU Materials Research Science and Engineering Center	New York U	NY
Princeton Center for Complex Materials	Princeton	NJ
Renewable Energy Materials Science and Engineering Center	Colorado School of Mines	CO
Research Triangle Materials Research Science and Engineering Center	Duke	NC
Soft Materials Research Centers	U of Colorado	CO
Nanoscale Science and Engineering Centers		
Center for the Environmental Implications of Nanotechnology (CEINT)	Duke	NC
Center for Integrated and Scalable Nanomanufacturing[2]	U of California-Los Angeles	CA
Nanotechnology in Society Network: Center at ASU	Arizona State U	AZ
Nanotechnology in Society Network: Center at UCSB	U of California-Santa Barbara	CA
National Nanomanufacturing Network: Center for Hierarchical Manufacturing	U of Massachusetts-Amherst	MA
Predictive Toxicology Assessment & Safe Implementation of Nanotechnology in the Environment (CEIN)	U of California-Los Angeles	CA
Science and Technology Centers		
BEACON: An NSF Center for the Study of Evolution in Action	Michigan State U	MI
Biology with X-Ray Lasers	SUNY Buffalo	NY
Center for Brains, Minds, and Machines: The Science and the Technology of Intelligence	Massachusetts Institute of Tech	MA
Center for Coastal Margin Observation and Prediction	Oregon Health and Science U	OR
Center for Dark Energy Biosphere Investigations	U of Southern California	CA
Center for Energy Efficient Electronics Science	U of California-Berkeley	CA
Center for Integrated Quantum Materials	Harvard	MA
Center for Layered Polymeric Systems	Case Western Reserve	OH
Center for Microbial Oceanography: Research and Education	U of Hawaii-Manoa	HI
Center for Multi-Scale Modeling of Atmospheric Processes	Colorado State	CO
Emergent Behaviors of Integrated Cellular Systems	Massachusetts Institute of Tech	MA
Center for the Science of Information	Purdue	IN
Science of Learning Centers		
Center for Excellence for Learning in Education, Science, and Technology	Boston U	MA
Spatial Intelligence and Learning Center	Temple	PA
The Temporal Dynamics of Learning Center	U of California-San Diego	CA

[2] These centers received no-cost award extensions in FY 2015 but no additional funding.

NSF EVALUATION AND ASSESSMENT CAPABILITY $8,860,000
+$0 / 0.0%

Overview

To develop a coordinated, agency-wide capacity for evidence-based program and policy decision-making, in FY 2013 NSF established an Evaluation and Assessment Capability (EAC) section in the Office of Integrative Activities. The need for such capability is reinforced by the Office of Management and Budget (OMB) memorandum,[1] M-15-11, that articulates the Administration's goals to: (1) harness data to improve agency results; (2) introduce and use high-quality, low-cost evaluations; and (3) strengthen agency capacity to use evidence in decision-making. Taken together, these activities will promote a culture of evaluation and assessment.

Total Funding for
Evaluation and Assessment Capability
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$6.84	**$8.86**	**$8.86**

Goals

The resources, expertise, and leadership of EAC will: (1) develop an effective culture of evidence-based planning and policy-making; (2) encourage increased rigor, independence, and consistency in all evaluations and assessments; and (3) develop and implement a coordinated evaluation framework that informs data collection, methods, and tools for evaluating NSF-wide investments. EAC staff provide expertise for rigorous evaluations, and assessments across the agency, aiming to be cost-effective while also providing support for consistent high quality, data-driven decision-making.

Approach

The NSF EAC has three interdependent structural components with three distinct areas of activity and responsibility:

- **Agency-wide Independent Coordination for Evaluation:** EAC cultivates an evaluation and assessment culture across NSF. It will refine a set of evaluation principles and a flexible framework for evaluation that can be adapted by all directorates and offices. Initially, this flexible framework will be used to assess progress towards the goals of three types of NSF programs: (1) human capital development; (2) agency-wide priority areas; and (3) long-term strategic investments. Careful attention will be paid to local needs, priorities, and expertise within each directorate and/or office. EAC will serve as a clearing-house and resource for program evaluations and will maintain a centralized repository for such evaluations. To encourage the growth of an evaluation culture within NSF, EAC will develop training courses and other relevant materials to facilitate staff use of evaluation tools and concepts in decision-making.
- **Directorate and Office Evaluation Capacity:** There is varying capacity for monitoring, assessment, and evaluation of programs across the directorates and offices. EAC will collaborate with them to enhance their evaluation and assessment capacity. EAC will inform evaluation activities across the agency, widely publicize its evaluation expertise, principles, and practices, and develop resources and skills that meet specific needs. EAC will collaborate on evaluations of key Foundation-wide programs, provide advice on evaluation design and data issues, and recommend models or resources, as needed, for evaluations managed in directorates and offices.

[1] www.whitehouse.gov/sites/default/files/omb/memoranda/2015/m-15-11.pdf

- **Strategic Data Collection, Tool Development, and Management:** EAC will develop methods for using NSF administrative data in its evaluation and assessment activities, including portfolio analysis. EAC will collaborate with the Office of Budget, Finance, and Award Management (BFA) and the Office of Information and Resource Management (OIRM) to provide systematic analyses of NSF administrative data, including awards/awardees, agency staffing, and budgetary allocations. This systematic analysis will allow NSF to assess its own practices and policies and inform its decision-making. Further, through collaboration with the National Center for Science and Engineering Statistics (NCSES), EAC will determine how NCSES data and NSF administrative data can be better integrated with NSF's program evaluations to describe the nature and scope of NSF's research portfolio, how its investments contribute to changes in the scientific knowledgebase as well as the science, technology engineering and mathematics (STEM) workforce and also to describe the broader impacts of these investments on society. EAC will also develop and implement enhanced portfolio analysis and monitoring tools.

Two NSF-wide groups will routinely provide advice on EAC's activities. First, the EAC Steering Committee, consisting of assistant directors and office heads, will provide senior leadership and strategic direction for EAC. Second, the EAC Working Group, consisting of program directors and division directors from the directorates and offices, will inform routine operations of EAC, facilitate collaborations across the agency, and provide local perspectives on EAC activities.

Investment Framework

FY 2015 – FY 2016

NSF recruited a permanent section head for EAC in FY 2015 and a full complement of staff, including evaluators and data scientists. In collaboration with NCSES, a statistician is expected to be on board in FY 2016.

Preliminary reports on an evaluation of Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) were received in FY 2015 with final reports expected in June 2016. NSF has initiated evaluations of human capital development programs and long-term strategic investments. In particular, multi-year evaluation and monitoring efforts for longitudinal data collection for the Graduate Research Fellowship Program (GRFP) and the Research Experience for Undergraduates (REU) are underway. A multi-year contract for an evaluation of the NSF Innovation Corps (I-Corps™) program was initiated in late FY 2015.

The NSF-wide Portfolio Analysis Tools Taskforce was convened in FY 2015 with representation from different types of programs. A needs assessment survey was conducted and an NSF-wide portfolio analysis tools requirements report was created. These activities have informed tool development and implementation, which will make these data analytic tools available to NSF staff in FY 2016. Specifically, the tools include both unsupervised and supervised techniques for mining textual data and their visualization. NSF has internal capacity to develop textual analysis tools based on unsupervised techniques that use word counts and proximity of terms in a document. The Division of Information Systems (DIS) is in the process of implementing such tools to make them available for use by NSF staff. For tools using supervised, thesaurus-based techniques, NSF is collaborating on joint tool development with National Institutes of Health (NIH). Initially this collaboration will include data sharing and pilot projects to develop thesauri that describe subsets of the NSF research portfolio.

FY 2017 Request

Within NSF, evaluation activities have traditionally been initiated and managed locally, within the directorate or office of the program being evaluated, and with little NSF-wide coordination. This distributed approach increases local knowledge and reinforces the NSF-wide expectation of evaluation of the impact of its investments. In partnership with all directorates and offices, EAC will coordinate NSF's evaluation and assessment practices and harmonize the use of evaluation framework(s). Specifically, EAC will:

- Recommend policies and procedures for evaluation data collection and use, and methods for conducting evaluations and assessments in general, as well for specific types of programs; and
- Develop and maintain resources, including evaluation training programs, a website, and a repository for evaluation reports.

In FY 2016, EAC will collaborate with relevant working groups to develop evaluation frameworks and statements of work for contracts beginning in FY 2017. As mentioned earlier, these evaluations will focus on three types of NSF programs: (1) human capital development; (2) agency-wide priority areas; and (3) long-term strategic investments.

EAC will implement the Portfolio Analysis Tools Taskforce recommendations by continuing investments in tool development both in-house and in collaboration with NIH. Such tool development will build upon work begun in FY 2016 to include enhanced text mining and visualization tools as well as thesauri containing categories, concepts, and terms that describe the research portfolios of the various NSF divisions and directorates. EAC will identify, in collaboration with DIS, system requirements for implementing portfolio analysis tools that integrate NSF administrative data.

FY 2018 – FY 2019

EAC will use the lessons learned from pilot activities in FY 2016 and FY 2017 to scale up its evaluation efforts and achieve a steady state of programs that (1) undergo rigorous and independent evaluations, (2) use evaluations to inform program decisions, and (3) provide new knowledge regarding mid-course corrections and adjustments.

EAC staff, the EAC Working Group, and the EAC Steering Committee will implement a flexible evaluation framework. Ongoing discussions with these experts will continue to strengthen evaluation and assessment capability across NSF.

EAC will continue to develop and implement portfolio analysis tools. EAC will begin to use administrative and longitudinal data in its program evaluations. It will also continue to provide staff training and disseminate evaluation tools and methods.

Evaluation Framework

In addition to conducting evaluations and assessments of NSF programs, EAC will also use multiple sources of expertise, data, and metrics to assess its own performance. Expert review of EAC's activities and feedback from EAC's collaborators via customer satisfaction surveys will provide important input into EAC's performance. In addition, the EAC Steering Committee and the EAC Working Group will provide ongoing feedback on the quality of evaluation reports and the usefulness of the findings for NSF. Feedback on the findings of the evaluations will be built into future evaluation contracts.

PROPOSAL MANAGEMENT EFFICIENCIES (PME) $9,430,000 +$740,000 / 8.5%

Overview

The merit review process is one of NSF's critical business functions. Effective merit review recognizes high-quality research, including high-risk, high-reward or potentially transformative ideas, empowers NSF to support such proposals, and retains the confidence and trust of NSF's external stakeholders. NSF's approach to merit review relies on NSF staff making funding recommendations advised by *ad hoc* (mail), virtual (teleconference, videoconference, or other online meeting technology), and/ or in-person panel review. This process is time- and resource-intensive.

In recent years, the number and increasing complexity of proposals have created a greater workload for researchers, reviewers, and NSF staff. NSF's eBusiness systems for managing the merit review process are based on old technologies that are expensive to maintain. Their functionality is dated and lags behind peer review management systems used by research journals and conference editors. The present proposal submission system is a barrier to the use of tools that could aid pre-review analysis, because it does not capture the content of proposals in a way that lends itself to use of modern textual and thematic analysis.

The Proposal Management Efficiencies (PME) activity is a continuing investment in improvements to NSF's proposal management systems that are designed to: reduce the number of reviewers who must travel to NSF; broaden participation in the merit review process; improve the management of reviewers, review requests, and reviews; improve compliance checking and conflict-of-interest management capabilities; improve data quality and capture proposal content in a way that supports data-mining and content analysis; simplify proposal submission; and assess the impacts of merit review pilot activities.

Total Funding for
Proposal Management Efficiencies
(Dollars in Millions)

FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
$12.45	**$8.69**	**$9.43**

Goal

The FY 2017 framework reflects updated goals for this investment. This activity will continue to broaden participation in the review process, reduce the average time commitment required of individual reviewers, increase the effectiveness of NSF program staff by reducing the clerical work required in basic proposal processing, improve the ability of NSF to identify potential conflicts of interest, and reduce the need to support outdated information technologies operating in parallel with more modern ones.

Approach

This activity consists of targeted investments aimed at improving NSF's systems and processes for managing proposals. It is a continuing part of a multi-year investment. This activity supports NSF's Strategic Plan through Strategic Goal 3: Excel as a Federal Science Agency, Strategic Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

Work on improving NSFs eBusiness systems will be undertaken by existing information technology staff and by contractors retained for this purpose. Support for virtual panels will continue to be provided by operational infrastructure staff and existing information technology specialist positions within the research directorates, together with a modest amount of contractor support.

Leadership structure and governance

The efforts to achieve proposal management efficiencies are coordinated by NSF's Enterprise Architecture Working Group (EAWG), which includes staff members from the research directorates, the Office of Integrative Activities, the Office of Information and Resource Management, and the Office of Budget, Finance, and Award Management.

Mechanisms to be used

The principal components of this plan are:

- Personnel and infrastructure to support use of virtual meeting technologies for review panels;
- Deployment of a more capable infrastructure to support the identification, selection, and recruitment of reviewers and to manage the subsequent receipt of reviews; and
- Increased use of automation in the preliminary processing of proposals.

A virtual panel pilot began in FY 2012 focusing on an investigation of available technologies to support the use of virtual panels. FY 2014 included funding for expanding NSF's ability to conduct virtual panels and incorporated some basic compliance checks into NSF's existing proposal submission system. In addition, in 2014, NSF's Capital Planning and Investment Committee recognized a need for continuous improvement to the proposal and review management systems and their supporting infrastructure, and recommended that proposal management efficiency improvements be supported at a sustained level that can be efficiently managed by NSF staff. Accordingly, the initial effort to revamp the proposal submission system and improve the merit review management systems began in FY 2015. These activities will improve integration between the component systems that make up NSF's proposal and review management architecture and provide better business intelligence functionality to support portfolio management. It is expected that the sustained improvement effort will continue indefinitely, guided by a multi-year roadmap that is updated each year by the EAWG. Budget projections through FY 2019 are based on the current roadmap.

Investment Framework

Proposal Management Efficiencies

Funding by Account

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Technological Support for Proposal and Review Management	$12.00	$8.25	$8.95
Virtual Meeting Technologies - IT	0.10	0.10	0.10
Subtotal, Program Related Technology (R&RA and EHR)	**$12.10**	**$8.35**	**$9.05**
Impact Assessment	0.35	0.34	0.38
Subtotal, Other Program Related Administration (R&RA and EHR)	**$0.35**	**$0.34**	**$0.38**
Total, Proposal Management Efficiencies	**$12.45**	**$8.69**	**$9.43**

Totals may not add due to rounding.

Specific investments include:

- Continued experimentation with new virtual meeting technologies;
- Technological support for proposal and review management; and
- Assessment of impacts of program management efficiencies.

The support for proposal and review management is comprised of improvements in those parts of NSF's IT systems used to conduct the merit review process. The multiple component activities are listed below and are coordinated in a holistic fashion by the EAWG in order to maintain an integrated enterprise system. This began in FY 2015 and will continue through FY 2019.

- Transition NSF's client-server eBusiness systems used in reviewer and panel management to web-based systems;
- Develop and deploy a more sophisticated database of reviewers, which is easily searchable according to a rich set of criteria, including keywords associated with expertise and review history;
- Make enhancements so that researchers and other experts can volunteer online to serve as reviewers, indicating their expertise, experience, availability, and information that can be used to perform a preliminary screen for conflicts-of-interest;
- Enhance tools that NSF staff use to identify possible reviewers to include the ability to automatically suggest potential reviewers based on matching key criteria such as proposal topics, reviewer expertise, and review history;
- Add an eBusiness system module that tracks review requests and responses, and that automatically sends reminders about outstanding requests to reviewers and NSF staff;
- Deploy an enhanced proposal submission system that will include a suite of functions essential for improving data quality, conflicts-of-interest identification and management, and compliance checking;
- Deploy a modern, rules-based, automated proposal compliance checking system integrated within NSF's proposal submission pipeline;
- Increase integration between the systems that make up NSF's proposal and review management architecture; and
- Provide enhanced business intelligence functionality to support portfolio management.

FY 2015 – FY 2016

Use of Virtual Meeting Technologies for Merit Review

Since FY 2012, the agency has piloted the use of virtual panels as a way to increase and broaden participation, lower costs, and improve the merit review process' efficiency while maintaining quality. After several years of investments aimed at expanding NSF's use of virtual panels for proposal review, the percentage of panels conducted wholly virtual was 29.6 percent in FY 2014 and 25.2 percent in FY 2015. A similar proportion of panels combine both physically present and virtual panelists. Most of this activity is being transitioned from the category of an IT investment to normal operations. Consequently, in FY 2016 and beyond, the only budget component of this activity that remains under proposal management efficiencies is $100,000 annually for licenses for experimentation with new virtual meeting technologies.

Technological Support for Proposal and Review Management

The activities already begun in FY 2015 or planned for FY 2016 include:

- Migrating merit review applications built on aging unstable client-server technology to modern web-based technology. The initial focus has been to migrate tools used to set up and conduct panels;
- The use of a unique customer ID system will be piloted, beginning with Graduate Research Fellows;
- The implementation of a reviewer invitation management system (beginning in FY 2016 with deployment in FY 2017);
- Modernizing proposal submission capabilities to provide workload efficiencies to NSF staff and the research community, implementing features that will further automate the preliminary processing of proposals, including increased automated checks for compliance with basic proposal requirements. So

far, NSF implemented automated compliance checking for a set of rules specific to the Grant Proposal Guide and a first set of solicitation-specific rules;
- Making new business intelligence capabilities available to program staff to help with reviewer selection and portfolio management. To date, new enterprise reporting tools have been added. These provide both pre-designed report types and a tool for creating custom-designed report types.

Assessment of Impacts of Proposal Management Efficiencies

To provide information on the impacts of Proposal Management Efficiency activities on external stakeholders, NSF has engaged an external party to conduct surveys of NSF reviewers and investigators to assess workload, the impacts of the technologies used to support merit review, and the quality of feedback provided to proposers. In addition to the activities described here, since FY 2012, NSF staff members have undertaken a number of pilot activities to test several approaches to achieving further efficiencies in the proposal management process. The surveys include the collection of ancillary data so that statistical analysis will be able to separate changes in the management of proposals and reviews, including merit review pilot activities, from confounding variables such as the effects of the research domain to which the proposals and reviewers belong, the type of home institution, and basic demographic data variables. The first survey was conducted in November 2015 and results will be available in May 2016. Surveys will be conducted annually thereafter.

FY 2017 Request

Use of Virtual Meeting Technologies for Merit Review

$100,000 annually for licenses for experimentation with new virtual meeting technologies.

Technological Support for Proposal and Review Management

The following activities will continue:
- The migration of merit review applications built on aging unstable client-server technology to modern web-based technology;
- The implementation of a modern, rules-based, automated proposal compliance checking system;
- Modernization of the proposal submission system; and
- The deployment of advanced proposal data management capabilities.

Assessment of Impacts of Proposal Management Efficiencies
- Data from the merit review survey conducted at the end of FY 2016 will be analyzed and used to provide information on the research community's experiences with NSF's merit review process; and
- The merit review survey will be repeated.

FY 2018 – FY 2019

Use of Virtual Meeting Technologies for Merit Review

The bulk of the support for the use of virtual meeting technologies has transitioned to normal operations. To incorporate the continual evolution of virtual meeting technologies, it is anticipated that $100,000 will be invested annually for licenses for experimentation with new virtual meeting technologies.

Technological Support for Proposal and Review Management
- The migration of merit review applications built on aging unstable client-server technology to modern web-based technology will continue;
- The implementation of a modern, rules-based, automated proposal compliance checking system will be completed in FY 2018;
- A new researcher database (principal investigators and reviewers) will be developed by FY 2019. It will include researcher self-registration capability, and tools for identifying potential reviewers based on matching key criteria such as proposal topics, reviewer expertise, and review history;

- Modernization of the proposal submission system will be a continuous activity;
- Interactive panel system services will be modernized during FY 2018 and FY 2019; and
- The deployment of advanced proposal data management capabilities will be a continuous process.

Assessment of Impacts of Proposal Management Efficiencies

- Data from the survey conducted towards the end of the prior fiscal year will be analyzed and used to provide information on the research community's experiences with NSF's merit review process; and
- The merit review survey will be repeated annually.

Evaluation Framework

The effectiveness of NSF's technological support for virtual meetings and proposal and review management will be monitored and evaluated by the EAWG based on status reports from the Division of Information Systems and feedback from NSF staff testing or using the technologies. EAWG meets monthly and receives a comprehensive quarterly update from DIS. EAWG provides guidance to DIS on adjustments to the program management efficiencies implementation roadmap, as required.

Quantitative and qualitative data on staff, reviewer, and PI demand will be obtained through surveys. Data on the individuals who participate in the merit review process will be obtained from NSF's Enterprise Information System. The number, size, duration and cost of virtual panels, as well as the per-proposal review costs of virtual and in-person panels will be obtained from internal administrative data. Changes in the tracked quantities will be analyzed to determine if the goals have been achieved. A statistical comparison of merit review indicators will be made, with some of that information being included in the National Science Board's annual report on the merit review process. NSF will discuss information gathered through the survey of proposers and reviewers with directorate advisory committees.

SELECTED CROSSCUTTING PROGRAMS

Many investments at NSF draw on interdisciplinary teams from across the Foundation and are supported by multiple directorates. Other parts of the NSF-Wide Investments chapter provide narratives for NSF-wide priority investments such as Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS); Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS); and Understanding the Brain (UtB). Selected cross-cutting programs at NSF are presented in the narrative below, and full funding data for these programs is provided in the Summary Tables chapter.

Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE)

In FY 2017, $14.10 million in funding is requested for the ADVANCE program, a decrease of $800,000 below the FY 2016 Estimate. ADVANCE funds transformative efforts to address the systemic barriers to women's full participation in academic science, technology, engineering, and mathematics (STEM) careers. In FY 2017, the ADVANCE program will focus on broadening the spectrum of institutions participating in the program to include more undergraduate and minority-serving institutions and community colleges. This focus aims to increase the participation and advancement of women across higher education in academic science and engineering careers. Additionally, as the NSF INCLUDES National Network of Alliances takes shape in FY 2017, a second focus will be the alignment of ADVANCE with the NSF INCLUDES broadening participation challenges through the use of supplemental funding and other special grant options. It is anticipated that ADVANCE and other existing programs in the NSF broadening participation portfolio will form linkages and new partnerships to leverage the NSF INCLUDES Alliance investments. Funding for ADVANCE in FY 2017 is provided by the Directorates for Biological Sciences (BIO); Computer and Information Science and Engineering (CISE); Education and Human Resources (EHR); Engineering (ENG); Geosciences (GEO); and Social, Behavioral and Economic Sciences (SBE).

Faculty Early Career Development (CAREER)

The FY 2017 Request provides $229.58 million for the CAREER program, an increase of $3.07 million over the FY 2016 Estimate. This funding level will support approximately 400 new CAREER awards, which support exceptionally promising college and university junior faculty who are committed to the integration of research and education and who are most likely to become the leaders in their fields. Funding for CAREER is provided by BIO, CISE, ENG, GEO, SBE, the Directorate for Mathematical and Physical Sciences (MPS), and the Office for International Science and Engineering (OISE).

Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE)

INSPIRE was established to address some of the most complex and pressing scientific problems that lie at the intersections of traditional disciplines and to advance the NSF's strategic goal to *Transform the Frontiers of Science and Engineering*. Dedicated funding is no longer necessary to encourage the kinds of projects supported through INSPIRE. Starting in FY 2017, each directorate will continue support for INSPIRE-like interdisciplinary research through core and cross-cutting programs, coordinating with other directorates and divisions, as necessary, for internal review of these projects. NSF anticipates developing a new funding mechanism that will manifest many of the principles of INSPIRE. This new funding mechanism will have guidelines published in the annual NSF Grants Proposal Guide, and will be available to any researcher conducting transformational, interdisciplinary research in fields that NSF supports.

Long-Term Ecological Research (LTER)

The FY 2017 Request provides $28.95 million for LTER, of which $27.95 million is discretionary funding and $1.0 million is new mandatory funding. This is an increase of $1.0 million above the FY 2016 Estimate. LTER supports fundamental ecological research that requires data collection over long time periods and often at large spatial scales. This program supports a loosely coordinated network of more than two dozen field sites that focus on: 1) understanding ecological phenomena that occur over long temporal and broad spatial scales; 2) creating a legacy of well-designed, long-term ecological experiments; 3) conducting major syntheses and theoretical efforts; and 4) providing information to identify and to address environmental problems. LTER projects represent a diversity of habitats in continental North America, the Caribbean, Pacific Ocean, and the Antarctic; including coral reefs, arid grasslands, estuaries, lakes, prairies, forests, alpine and Arctic tundra, urban areas, and agroecosystems. The increased support for LTER in FY 2017 will be used to stimulate new research activities, including the establishment of new project sites, examining evolutionary change in populations and communities that have been studied for over 30 years, and conducting syntheses of long-term data using contemporary modeling methods. Funding for LTER is provided by BIO, GEO, and SBE.

National Ecological Observatory Network (NEON) infrastructure will be co-located at eleven LTER sites. NEON is a continental-scale infrastructure facility providing standardized physical and data resources to researchers and educators. LTER is a network of long-term research projects aimed at understanding ecological processes in a wide range of ecosystems. Ongoing research at LTER sites may take advantage of data generated using NEON infrastructure. In addition, the co-location of NEON infrastructure at LTER sites will stimulate new research that builds on the long history of LTER research by enhancing the ability to extend site-based knowledge to regional and continental scales. For more information on NEON, see the NEON narrative in the Major Research Equipment and Facilities Construction chapter.

Research Experiences for Undergraduates (REU)
In FY 2017, $75.58 million in funding is requested for the REU Sites and Supplements program, an increase of $150,000 above the FY 2016 Estimate. NSF's ongoing support for REU reflects the importance of undergraduate research experiences in building students' interest and competence in STEM disciplines, and aligns with the Administration's focus on improving undergraduate STEM education. REU grants involve students at all stages of undergraduate education. REU Supplements allow students to join research projects that are supported by NSF research grants. REU Sites support cohorts of students to conduct research within STEM disciplines or on topics that cut across disciplines. Most of the students in an REU Site come from outside the host institution. This feature enables the program to involve students in research who might not otherwise have the opportunity, particularly students from institutions where faculty research activities are limited. The REU program encourages partnerships between community colleges and baccalaureate degree-granting institutions to provide research opportunities for community college STEM students and faculty. NSF's REU Sites and Supplements programs fall within the Improving Undergraduate STEM Education framework as affiliated programs, with budget and award decisions remaining within individual directorates. Funding for REU is provided by BIO, CISE, ENG, GEO, MPS, and SBE.

Research in Undergraduate Institutions (RUI)
The FY 2017 Request for NSF's RUI program totals $40.15 million; this is $1.0 million above the FY 2016 Estimate. The increase in funding will allow the RUI activity to increase its support of high quality research by faculty members of predominantly undergraduate institutions, strengthen the research environment in academic departments that are primarily oriented toward undergraduate instruction, and promote the integration of research and education of undergraduate students. RUI proposals are accepted in all fields of science and engineering supported by NSF, including research on learning and education. Funding for RUI is provided by BIO, CISE, GEO, MPS, and SBE.

NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

Total Funding for NNI
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$48.80	$48.80	$48.80
Computer and Information Science and Engineering	13.75	13.75	13.75
Education and Human Resources	2.50	2.50	2.50
Engineering	219.95	168.50	168.50
Geosciences	0.30	0.30	0.30
Mathematical and Physical Sciences	203.07	180.62	180.37
Social, Behavioral, and Economic Sciences	1.30	0.53	0.53
Office of International Science and Engineering	0.10	0.10	0.10
Total, NNI	**$489.77**	**$415.10**	**$414.85**

Totals may not add due to rounding.

NSF's contribution to the multiagency National Nanotechnology Initiative (NNI) encompasses the systematic understanding, organization, manipulation, and control of matter at the atomic, molecular, and supramolecular levels in the size range of about 1 to 100 nanometers. Novel materials, devices, and systems – with their building blocks designed on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to control and manipulate matter at this scale, science, engineering, and technology researchers are realizing revolutionary advances in areas such as order-of-magnitude faster computers with less energy consumption; catalysts for industry; molecular medicine; imaging and understanding of the brain; nanosensors to monitor health and the environment; efficient and large-scale nanomanufacturing; more resilient materials and system architectures; and sustainable development for water, energy, and food resource utilization. NSF contributes to the NNI goals and five Program Component Areas (PCAs) outlined in the 2014 NNI Strategic Plan and the NNI Supplement to the President's Budget for Fiscal Year 2017.[1] Funding by PCA is shown at the end of this discussion.

<u>FY 2017 NNI Funding</u>

NSF supports nanoscale science and engineering throughout all the research and education directorates as a means to advance discovery, invention, and innovation and to integrate various fields of research. NNI enables increased interdisciplinarity at atomic and molecular levels for about 6,000 active awards with full or partial contents on nanoscale science and engineering (NSE). Approximately 10,000 students and teachers will be educated and trained in NSE in FY 2017.

Overall, total NNI funding in the FY 2017 Request is $414.85 million, a decrease of $250,000 from the FY 2016 Estimate of $415.10 million.

Several new directions planned for FY 2017 are nanotechnology for brain-like computing, nanobiomanufacturing, food-energy-water processes, nanomodular materials and systems by design including two-dimensional nanoscale materials, and emerging aspects of nanoelectronics, photonics, and neuroscience. NSF sponsors an annual NSE grantee conference to assess the progress in nanotechnology and facilitate identification of new research directions.[2]

[1] www.nano.gov
[2] 2015 Nanoscale Science and Engineering Grantees Conference: www.nsf.gov/nano and www.nseresearch.org/2015

In FY 2017, NSF support will increasingly focus on convergence research and education activities in confluence with other priority areas such as: the National Strategic Computing Initiative (NCSI); Science, Engineering, and Education for Sustainable Chemistry, Engineering and Materials (SusChEM); Research at the Interface of Biological, Mathematical and Physical Sciences, and Engineering (BioMaPS); Designing Materials to Revolutionize and Engineer our Future (DMREF); Materials Genome Initiative; Smart Systems; Quantum Information Science and Engineering; and synthetic biology. Partnerships of new NERCs with small businesses in the areas of nanomanufacturing and commercialization will be strengthened while maintaining about the same level of NSF investment. A new industrial internship in emerging nanotechnology areas is planned with IBM. NSF continues its contributions to translational innovation programs, including Grant Opportunities for Academic Liaison with Industry (GOALI); Industry/University Cooperative Research Centers (I/UCRC); the NSF Innovation Corps (I-Corps™) program; and the two subcomponents of Partnerships for Innovation (PFI): Accelerating Innovation Research (AIR) and Building Innovation Capacity (BIC). The NSF Small Business Innovation Research (SBIR) program has an ongoing nanotechnology topic with subtopics for nanomaterials, nanomanufacturing, nanoelectronics and active nanostructures, nanotechnology for biological and medical applications, and instrumentation for nanotechnology.

NSF sponsored an international study on long-term research entitled *Nanotechnology Research Directions for Societal Needs in 2020.*[3] It provides an assessment of nanotechnology development in the last ten years (2000-2010) and a vision of the field for the next decade (2010-2020). This study evaluates the outcomes recommended by the first report issued in 1999, *Nanotechnology Research Directions: A vision for the next decade*, which was adopted as an official document of the National Science and Technology Council (NSTC). With the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), Office of Naval Research (ONR) and the U.S. Department of Agriculture (USDA), NSF co-sponsored the study entitled *Converging Knowledge, Technology, and Society*[4] evaluating the convergence of nanotechnology with other emerging areas. A follow-up report on *Science and Technology Convergence* will be completed in 2016. A study on *Nanomodular Materials and Systems by Design* to identify international activities and research directions will be completed in 2016.[5] The 2015 workshop “Rebooting the IT Revolution” was conducted in collaboration with the Semiconductor Industry Association (SIA), the Semiconductor Research Corporation (SRC), the National Institute of Standards and Technology (NIST) and the Defense Advanced Research Projects Agency (DARPA). The purpose of this workshop was to define Grand Challenges, one of them being “Brain-like Computing.” The report addresses aspects of fundamental research for energy-efficient sensing and computing, data storage, real-time communication ecosystem, multi-level and scalable security, a new fabrication paradigm, and insight computing. [6,7]

Program Component Areas (PCAs) are the major subject areas of relevance to the NNI agencies, where progress is critical to achieving the NNI's goals and to realizing its vision.[8] NSF supports funding in all five PCAs.

PCA 1: Nanotechnology Signature Initiatives (NSIs)

The first PCA, which encompasses the five Nanotechnology Signature Initiatives (NSIs), will increase by $2.0 million to a total of $92.52 million. The changes are in the Sustainable Nanomanufacturing NSI with an increase of $2.0 million for research on manufacturing for nanosystems and nanomodular materials. The Nanotechnology for Solar Energy Collection and Conversion NSI graduated in FY 2015, and there are plans for a new NSI on Nanotechnology for Water. Special emphasis will be on:

[3] NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/
[4] NSF/WTEC 2013, Springer, available on www.nsf/gov/nano and www.wtec.org/NBIC2-Report/
[5] http://www.wtec.org/nmsd/
[6] http://1.usa.gov/1Fg90Dw
[7] https://src.org/newsroom/rebooting-the-it-revolution.pdf
[8] http://www.nano.gov/nni-pca

- Sustainable Nanomanufacturing ($28.40 million) – Establishing manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems by supporting product, tool, and process design informed by and adhering to the overall constraints of safety, sustainability, and scalability. This signature initiative specifically focuses on high-performance structural carbon-based nanomaterials, optical metamaterials, and cellulosic nanomaterials. This initiative will establish manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems. A program solicitation on Scalable Nanomanufacturing will be announced in FY 2016 and another is planned for FY 2017. Engineering biology at the nanoscale for advanced manufacturing activities in the Directorates for Biological Sciences (BIO) and Engineering (ENG) are being organized for 2016 and 2017.
- Nanoelectronics for 2020 and Beyond ($37.50 million) – Discovery and use of novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of nanoelectronics. This initiative is aimed at discovering and using novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of electronics. Collaboration in the Nanoelectronics Research Initiative with SRC and NIST is planned to continue in FY 2017. Research will address the NNI Grand Challenge "Brain-like Computing." Two examples of active centers are the Science and Technology Center (STC) on Quantum Materials and Devices at Harvard University and the MRSEC on Quantum and Spin Phenomena in Nanomagnetic Structures at the University of Nebraska, Lincoln.
- Nanotechnology Knowledge Infrastructure ($19.12 million) – Activities surrounding the fundamental, interconnected elements of collaborative modeling, a cyber-toolbox, and data infrastructure for nanotechnology, leveraging and extending existing and emerging resources, programs, and technologies to create an infrastructure to accelerate the vetting of new knowledge and to enable effective data utilization. This initiative aims to provide a community-based, solution-oriented knowledge infrastructure for discovery, innovation, and nanoinformatics of research, education and regulatory interest to NNI agencies. The Network for Computational Nanotechnology (NCN) conducts key activities in support to this NSI and is planned to be re-competed in 2017.
- Nanotechnology for Sensors and Sensors for Nanotechnology ($7.50 million) – Use of nanotechnology and nanoscale materials to build more sensitive, specific, and adaptable sensors and the development of new sensors to detect engineered nanomaterials across their life-cycles to assess their potential impacts. This initiative supports materials and technologies that enable new sensing of biological, chemical, and nanoscale materials, including sensors for nano environment, health, and safety (nano-EHS). A dedicated program on nanobiosensors in the Chemical, Bioengineering, Environmental, and Transport Systems (CBET) division in ENG will support this effort.

PCA 2: Foundational Research

The FY 2017 Request includes $210.47 million for the discovery and development of fundamental knowledge pertaining to new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale. Also included is funding for research aiming to understand scientific and engineering principles related to nanoscale systems, structures, processes, and mechanisms; research on the discovery and synthesis of novel nanoscale and nanostructured materials including biomaterials and modular structures; and research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, ethical, and legal implications. About 60 percent of the MRSECs pursue NSE-related fundamental research.

PCA 3: Nanotechnology-Enabled Applications, Devices, and Systems

The FY 2017 Request includes $44.56 million for research that applies the principles of nanoscale science and engineering to create novel devices and systems, or to improve existing ones. This includes the incorporation of nanoscale or nanostructured materials and the processes required to achieve improved performance or new functionality, including metrology, scale up, manufacturing technology, and nanoscale reference materials and standards. The NERC for Nanotechnology-Enabled Water Treatment at Rice University investigates distributed water filtration methods.

PCA 4: Research Infrastructure and Instrumentation
The FY 2017 Request includes $45.66 million for the establishment and operation of user facilities and networks, acquisition of major instrumentation, workforce development, and other activities that develop, support, or enhance the Nation's physical or human infrastructure for nanoscale science, engineering, and technology. This PCA includes research pertaining to the tools needed to advance nanotechnology research and commercialization, including next-generation instrumentation for characterization, measurement, synthesis, and design of materials, structures, devices, and systems. While student support to perform research is captured in other categories, dedicated educational and workforce efforts, ranging from curriculum development to advanced training, are included here as resources supporting the human infrastructure of the NNI. In FY 2015, NSF awarded the National Nanotechnology Coordinated Infrastructure (NNCI) sites, whose national coordination office will be added in FY 2016. NNCI, which replaces the National Nanotechnology Infrastructure Network (NNIN), has an annual budget estimated at $16 million. One new NERC was awarded in FY 2015, and a new ERC competition will be completed in FY 2017 which could include additional NERCs. NSF continues to sponsor nanotechnology education and related activities, such as the FY 2016 video series with NBC Learn, "Nanotechnology: super small science," and student competition "Generation Nano".[9]

PCA 5: Environment, Health, and Safety
In FY 2017, NSF will continue its funding for the Environment, Health, and Safety (EHS) PCA at $21.64 million, representing roughly 5.2 percent of its overall NNI budget. Requests for research are primarily directed at understanding nano-bio phenomena and processes, as well as environment, health, and safety implications and methods for reducing the respective risks of nanotechnology development. NSF continues to sponsor two Centers for Environmental Implications of Nanotechnology at the University of California, Los Angeles (UCLA) and Duke University.

Coordination with Other Agencies
The NSF NNI program is coordinated with 20 departments and agencies through the NSTC subcommittee on Nanoscale Science, Engineering and Technology (NSET). These agencies also partner with NSF to sponsor joint workshops on nanotechnology research directions and send representatives to participate in grantees conferences. Some specific coordination efforts are:

- Sustainable Nanomanufacturing – NSF with NIST, Department of Energy (DOE), EPA, NIH, National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), USDA/Food Safety (FS);
- Two-Dimensional Atomic-layer Research and Engineering (2-DARE) program (4-year awards begun in FY 2014 and FY 2015) – NSF and Department of Defense (DOD)/Air Force Office of Scientific Research (AFOSR);
- Nanoelectronics – NIST, DOD, DOE, Intelligence Community (IC)/Director of National Intelligence (DNI), NASA;
- Environmental issues, including the planned competition for a "Consumer Products nano Center" – EPA, USDA/National Institute of Food and Agriculture (NIFA), Consumer Product Safety Commission (CPSC);
- NSECs, NNIN, and NCN centers and networks – NSF with DOD, NASA, DOE, NIH;
- Nanosensors – NSF, NIH, and USDA;
- Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) program – NSF and USDA/NIFA joint solicitation; and

[9] www.nsf.gov/news/special_reports/gennano/index.jsp

- Organization for Economic Cooperation and Development (OECD) (Working Group on Bio, Nano, and other Converging Technologies) and other international forum activities – participation by NSF in collaboration with State Department and other NNI agencies.

NNI Funding by Program Component Area

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
1. Nanotechnology Signature Initiatives	$158.58	$90.52	$92.52
Nanotechnology for Solar Energy	*24.91*	-	-
Sustainable Nanomanufacturing	*34.11*	*26.40*	*28.40*
Nanoelectronics for 2020 and Beyond	*60.75*	*37.50*	*37.50*
Nanotechnology Knowledge Infrastructure	*23.81*	*19.12*	*19.12*
Nanotechnology for Sensors	*15.01*	*7.50*	*7.50*
2. Foundational Research	210.85	212.72	210.47
3. Nanotechnology-Enabled Applications, Devices, and Systems	54.77	44.56	44.56
4. Research Infrastructure and Instrumentation	40.48	45.66	45.66
5. Environment, Health, and Safety	25.09	21.64	21.64
Total, NNI	**$489.77**	**$415.10**	**$414.85**

Totals may not add due to rounding.

NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$99.00	$99.00	$99.00
Computer and Information Science and Engineering	932.98	935.82	994.80
Education and Human Resources	9.50	9.50	9.50
Engineering	28.97	29.30	29.80
Geosciences	24.00	24.00	24.00
Mathematical and Physical Sciences	79.87	70.13	69.17
Social, Behavioral, and Economic Sciences	30.97	28.14	28.14
Total, NITRD	**$1,205.29**	**$1,195.89**	**$1,254.41**

NSF's FY 2017 Budget Request for the Networking and Information Technology Research and Development (NITRD) program is $1.25 billion, of which $1.19 billion is discretionary funding and $56.37 million is new mandatory funding. New mandatory funding for NITRD represents increased support for NITRD research in FY 2017 by the Computer and Information Science and Engineering (CISE) directorate. Details on new mandatory funding by NITRD Program Component Area (PCA) are listed below.

NSF is a primary supporter of the NITRD program, and NSF's NITRD portfolio includes all research, infrastructure, and education investments in CISE, as well as contributions from all other directorates across the agency, enabling investments in every NITRD PCA. NSF's Assistant Director for CISE is co-chair of the NITRD Subcommittee of the National Science and Technology Council's Committee on Technology. In addition, NSF works in close collaboration with other NITRD agencies and participates at the co-chair level in most of the PCA Coordinating Groups and three of the Senior Steering Groups.

In August 2015, the President's Council of Advisors on Science and Technology (PCAST) released the *Report to the President and Congress Ensuring Leadership in Federally Funded Research and Development in Information Technology*.[1] The report provides the PCAST's findings from its biennial review of the NITRD program and recommendations for modernizing the program's R&D investment portfolio and coordination process. The 2015 PCAST review of the NITRD program included a recommendation to revise the NITRD R&D investment portfolio to reflect both the current nature of information technology (IT) and the national priorities in which IT plays a major role. In response, the number of PCAs increased from eight to 10. Of the 10 PCAs, four are new (Enabling-R&D for High-Capability Systems; High Capability Computing Systems Infrastructure and Applications; Large-Scale Data Management and Analysis; and Robotics and Intelligent Systems). Three are impacted by the newly defined PCAs (Human Computer Interaction and Information Management; High Confidence Software and Systems; and Large Scale Networking), with the definition of one (Human Computer Interaction and Information Management) changing. The remaining three are unchanged (Cyber Security and Information Assurance; Software Design and Productivity; and Social, Economic, and Workforce Implication of IT and IT Workforce Development). Two of the eight PCAs previously used to describe the NITRD portfolio

[1] *Report to the President and Congress Ensuring Leadership in Federally Funded Research and Development in Information Technology*. August 2015, President's Council of Advisors on Science and Technology: https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/nitrd_report_aug_2015.pdf

(High End Computing Infrastructure and Applications (HEC I&A) and High End Computing R&D (HEC R&D)) were retired as part of this revision as well.

Several NSF-wide investments, both new and continuing, are reflected in various NITRD PCAs:

- The Comprehensive National Cybersecurity Initiative (CNCI) supports activities in Cybersecurity and Information Assurance.
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS), a collaboration among the Biological Sciences (BIO), CISE, Engineering (ENG), Education and Human Resources (EHR), and the Mathematical and Physical Sciences (MPS) directorates, includes Advanced Manufacturing, Designing Materials to Revolutionize and Engineer our Future (DMREF), and Smart Systems, which will span a new investment area in Smart and Autonomous Systems (S&AS) as well as existing investments in Cyber-Physical Systems (CPS) and the National Robotics Initiative (NRI). CEMMSS is establishing a scientific basis for engineered systems interdependent with the physical world and social systems, is synthesizing multi-disciplinary knowledge to model and simulate systems in their full complexity and dynamics, and is developing a smart systems technology framework. CEMMSS supports activities primarily in High Confidence Software and Systems; Robotics and Intelligent Systems; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development. Additionally, the advanced manufacturing investment encompasses research in nanotechnology, cyber-physical systems, and robotics, as well as expanded industry/university cooperation. Activities are supported primarily in High Confidence Software and Systems, and Robotics and Intelligent Systems.
- Cyberinfrastructure Framework for 21st-Century Science, Engineering, and Education (CIF21), a collaboration among all NSF directorates, primarily supports investments in Enabling-R&D for High-Capability Computing Systems; High Capability Computing Systems Infrastructure and Applications; Large-Scale Data Management and Analysis; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development. CIF21 will conclude at the end of FY 2017; however, support for NITRD investments in this area will begin to transition to new activities as part of the new Data for Scientific Discovery and Action (D4SDA) investment area and the National Strategic Computing Initiative (NSCI) (see below).
- Data for Scientific Discovery and Action (D4SDA) is a cross-directorate investment that will enable moving 21st-century science, engineering, and education toward effective use of digital data to advance discovery. This investment supports Large-Scale Data Management and Analysis.
- The National Strategic Computing Initiative (NSCI), an NSF-wide investment led by CISE and MPS, aims to maximize the benefits of high-performance computing (HPC) for scientific discovery and economic competitiveness. The NSCI investment supports Enabling-R&D for High-Capability Computing Systems; High Capability Computing Systems Infrastructure and Applications; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- The Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) NSF-wide investment, supports Cybersecurity and Information Assurance; High Confidence Software and Systems; Large-Scale Data Management and Analysis; and Large Scale Networking.
- Investments in NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science), a collaboration among all NSF directorates, support the Social, Economic, and Workforce Implications of IT and IT Workforce Development activity.
- The Risk and Resilience NSF-wide investment, a collaboration among the CISE, ENG, GEO, and Social, Behavioral, and Economic Sciences (SBE) directorates supports primarily Enabling-R&D for High-Capability Computing Systems; High Confidence Software and Systems; Large Scale Networking; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- Secure and Trustworthy Cyberspace (SaTC), a collaboration among CISE, EHR, ENG, MPS, and SBE, aligns NSF's cybersecurity investments with recent federal cybersecurity strategies including

Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program;[2] the government-wide Comprehensive National Cybersecurity Initiative (CNCI); and the recent Cybersecurity Enhancement Act of 2014 (P.L. 113-274). SaTC supports the research and education that will ensure society's ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. The SaTC investment supports Cybersecurity and Information Assurance; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- NSF investments in Smart & Connected Communities (S&CC), a collaboration among CISE, EHR, ENG, GEO and SBE, supports High Confidence Software and Systems, Human-Computer Interaction and Information Management, Large-Scale Data Management and Analysis, and Large Scale Networking activities.
- The Understanding the Brain (UtB) investment, a collaboration among BIO, SBE, CISE, EHR, ENG, and MPS, supports activities in High Confidence Software and Systems; Human Computer Interaction and Information Management; and Social, Economic, and Workforce Implications of IT and IT Workforce development. These activities also support part of NSF's contributions to the Administration's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.

FY 2017 NSF Investments by Program Component Area (PCA)

The following information focuses on FY 2017 NSF investments, both new and continuing, by PCA.

<u>Cybersecurity and Information Assurance (CSIA) ($117.11 million: $110.98 million in discretionary funding, $6.13 million in new mandatory funding)</u>: CSIA includes support for CNCI and NSF's SaTC program. Increased CISE investments in SaTC, in partnership with ENG, MPS, and SBE, aim to support the research that will ensure society's ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. This area also includes support from CISE for the NSF-wide INFEWS investment, with a focus on ensuring the safety and security of food, energy, and water resources, and the systems that facilitate their generation, distribution, and consumption through comprehensive, integrated research and modeling of these sociotechnical systems.

<u>Enabling-R&D for High-Capability Computing Systems (EHCS) ($137.59 million: $130.98 million in discretionary funding, $6.61 million in new mandatory funding)</u>: EHCS includes support for CISE's nanotechnology research. EHCS also includes increased support for research in Clean Energy Technologies by CISE, focusing on research that will develop the theory and design principles to tackle energy versus computation and communication tradeoffs effectively; and the development of new theory, algorithms, and design principles to optimize energy-computational performance in high-capability computing and communications systems. Through investments in NSCI, EHCS will support advances in HPC systems, increasing the capacity, capability, and sustainability of an enduring national HPC ecosystem. EHCS also includes support for CIF21 to develop new functional capabilities in support of highly parallel computing and big data analytics; and CISE support for Risk and Resilience, enabling advances in large-scale resilient, secure, and interoperable research cyberinfrastructure. MPS will support research to advance computational algorithms and data analytics to address scientific and engineering challenges presented by the ever-expanding role of computational modeling and simulation combined with the explosion of data coming from digital and observational data sources. MPS also will support fundamental research on innovative materials integration and novel phenomena associated with quantum information science, optical computing, and neuro-computing.

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[2] www.whitehouse.gov/sites/default/files/microsites/ostp/fed_cybersecurity_rd_strategic_plan_2011.pdf

<u>High-Capability Computing Systems Infrastructure and Applications (HCSIA) ($190.41 million: $183.19 million in discretionary funding, $7.22 million in new mandatory funding)</u>: HCSIA includes increased efforts by the Advanced Cyberinfrastructure (ACI) division in CISE to develop software and algorithms for high-end computing systems as well as advanced computational infrastructure in alignment with NSCI. HCSIA also includes MPS, ENG, and CISE investments in new computational methods, algorithms, scientific databases, and other computational tools to support researchers in the mathematical and physical sciences, and engineering through support for programs such as Computational and Data-Enabled Science and Engineering. The CISE investment in computational infrastructure as part of CIF21 is reflected here alongside GEO's support for EarthCube, a cyberinfrastructure investment for the geosciences. GEO's continued support for the operations and maintenance of the National Center for Atmospheric Research (NCAR) Wyoming Supercomputer facility and associated modeling efforts also is reflected in this area. HCSIA also includes BIO's support for the application of high performance computing to a range of grand challenge problems in the biological sciences including, Understanding the Brain (UtB), genotype to phenotype, and the environmental sciences.

<u>High Confidence Software and Systems (HCSS) ($91.08 million: $86.53 million in discretionary funding, $4.55 million in new mandatory funding)</u>: CISE will provide initial support for a new investment on Smart & Autonomous Systems as part of CEMMSS that will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. Along with ENG, CISE will also support advanced manufacturing technologies research in cyber-physical systems, including cybermanufacturing, such as smart infrastructure that will blend traditional concrete-and-steel physical infrastructure systems with cyberinfrastructure systems such as computers, networks, and sensors. CISE's support for HCSS also includes investments in INFEWS and UtB. INFEWS investments focus on innovative optimization techniques, algorithms, and software development. UtB investments (which include support of the BRAIN Initiative) seek to foster new computational models across multiple scales, from molecules to behavior, toward accomplishing the ultimate goal of establishing an integrative, quantitative, and predictive theory of brain function in action and in context. Additionally, as part of a new NSF-wide activity on S&CC, CISE, in collaboration with EHR, ENG, GEO and SBE, will support fundamental research on advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities. BIO's support for HCSS will expand and enhance access to the national resource of digital biological and paleontological data, and the Bio/computation Evolution in Action CONsortium (BEACON) Center established to study the power of evolutionary processes and to transfer those discoveries from biology into computer and information science and engineering design.

<u>Human Computer Interaction and Information Management (HCI&IM) ($190.79 million: $183.19 million in discretionary funding, $7.99 million in new mandatory funding)</u>: HCI&IM includes CISE support for S&CC, Smart and Connected Health (SCH), and UtB. S&CC supports the decision making, together with the necessary community building efforts, to improve quality of life, health, well-being, and learning in smart and connected communities. SCH support will focus on human-centered intelligent information systems and tools that collect, mine, synthesize, protect, and share appropriate data and knowledge with healthcare organizations, practitioners, caregivers, and individuals to enable effective, safe, and well-informed decision-making by all stakeholders. UtB investments will enable the research needed to integrate computational models across scales; the development of innovative neurotechnologies to monitor brain function; and the expansion of the capacity of neuroscience infrastructure to integrate data across levels of analysis from molecular to behavioral scales.

HCI&IM also includes ENG's support of projects to harness group expertise, intelligence, and insights as well as BIO's support of BIO team-based approaches to the understanding of complex biological processes through activities such as the Synthesis and Cyberinfrastructure Centers. These centers enable research communities to manage and utilize large data sets and other information in efficient ways for best advancing progress in the biological sciences. MPS investments include continued support for user interface work funded by the Division of Astronomical Sciences, both through its regular research grants program, and from its observatories, who are charged to serve their user communities with archives and human computer interface tools. MPS also will support the provision of new automated data-analysis pipelines that will provide initial reference images for the data-rich radio interferometers, with analysis tools and guidance for those scientists who need to interact with the data in order to achieve image fidelities beyond those that can be delivered using automated processing techniques.

<u>Large-Scale Data Management and Analysis (LSDMA) ($115.19 million: $111.25 million in discretionary funding, $3.94 million in new mandatory funding)</u>: LSDMA includes NSF investments in CIF21 and D4SDA related to BIGDATA analytics and visualization tools, and the development of mid-scale pilots and prototypes toward a comprehensive, scalable data infrastructure as part of Data Infrastructure Building Blocks (DIBBs). Through NSF’s support of the new D4SDA investment, LSDMA will focus on the development of novel computational, statistical, and mathematical techniques and technologies for data mining, machine learning, knowledge extraction, visualization, predictive modeling, automated discovery, and decision making, as applied to big data challenges. LSDMA also includes support for INFEWS focusing on novel approaches for large-scale, real-time data analytics. S&CC will support fundamental research on technologies integrating data-intensive computing; physical sensors/devices; and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities.

LSDMA also includes ENG's support of the cyberinfrastructure for the Natural Hazards Engineering Research Infrastructure (NHERI), which provides access to, and the storage and analysis of massive amounts of data related to natural disasters. A number of exploratory research projects in data analytics are also included. Moreover, the PCA includes support for CIF21 Investments from SBE such as the Resource Implementations for Data Intensive Research in the Social Behavioral and Economic Sciences (RIDIR) program and its contribution in support of the NSF-wide Public Access activity. Additional support from BIO related to this PCA includes research focused exclusively on managing large diverse data sets in order to extract knowledge from them, in particular, for the integrative modeling of complex biological processes. MPS support in this area includes support for research efforts to develop and advance theories and techniques for analyzing and extracting information from large and disparate data sets.

<u>Large Scale Networking (LSN) ($147.34 million: $139.02 million in discretionary funding, $8.32 million in new mandatory funding)</u>: Through INFEWS, CISE will invest in research related to control, automation, and optimization of the complex systems underlying the nexus of food, energy, and water. Moreover, CISE will support advances in large-scale resilient, secure, and interoperable research cyberinfrastructure through the Risk and Resilience investment area. As part of S&CC, LSN will support a network of regional research hubs that will advance fundamental research in advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities. CISE will also provide additional support for next-generation software-defined infrastructure, including wireless testbeds that enable research on topics ranging from radio access networks to spectrum sharing and adaptability.

<u>Robotics and Intelligent Systems (RIS) ($45.37 million: $43.49 million in discretionary funding, $1.88 million in new discretionary funding)</u>: CISE will provide initial support for a new investment on S&AS as part of CEMMSS that will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. In addition, RIS will include continued support for NRI, a component of CEMMSS and research in ENG related to the design, application, and use of robotics to augment human function, promote human-robot interaction, or to increase robot autonomy. As part of the next generation of robotics, co-

robot systems will be characterized by their flexibility and resourcefulness. They will use a variety of modeling or reasoning approaches, along with real-world data in real-time, demonstrating a level of intelligence and adaptability seen in humans and animals. As development of the next generation of robotics proceeds, complete confidence in the systems supporting those that work beside, or cooperatively with, people in application domains, such as advanced manufacturing, emergency response, and healthcare, become increasingly important.

<u>Software Design and Productivity (SDP) ($86.37 million: $82.73 million in discretionary funding, $3.64 million in new mandatory funding)</u>: SDP support reflects investment in CIF21 and NSCI, with a focus on software sustainability, and new research on smart systems as part of CEMMSS. ENG's support for this PCA is primarily associated with the CPS and NRI components of the CEMMSS investment. CISE will make investments in the Software Institutes for Sustained Innovation (SI^2) program to catalyze new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable under the CIF21 umbrella. SI^2 support will transition to NSCI as CIF21 sunsets. BIO support for SDP includes support for the interagency and international Collaborative Research in Computational Neuroscience program. BIO funds research involving the development of software and other computational tools to advance biological knowledge and computational innovations. SBE will continue to collaborate with CISE in exploring the emerging interface between computer and information science and the social, behavioral, and economic sciences as part of its support for SDP.

<u>Social, Economic, and Workforce (SEW) Implications of IT and IT Workforce Development ($133.16 million, $127.07 million in discretionary funding, $6.09 million in new mandatory funding):</u> As part of NRI, SEW research in CISE will focus on human-centered research in developing service robots, requiring significant advances in human-robot interaction. In addition, CISE's continued emphasis on SCH focuses on, for example, improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies. CISE, ENG, and EHR will also continue to support the Cyberlearning and Future Learning Technologies program, which aims to integrate advances in technology with advances in understanding how people learn, with a focus on online learning environments. Some of these investments will transition to S&CC, which will support health- and learning-related research in support of smart and connected communities. SEW also reflects CISE support for e-science collaboration tools as part of CIF21.

EHR will continue to study the impact of information and communication technology on educational practice, new approaches to using technology in education, application and adaptation of technologies to promote learning in a variety of fields and settings, the effects of technology of learning, and efforts that advance teaching and learning opportunities utilizing cyberinfrastructure as part of its support. CISE will collaborate with EHR to support cyber-secure workforce development to enable a growing pipeline of researchers and educators, and to develop a citizenry that understands the security and privacy of the digital systems on which society depends. These efforts also will support science, technology, engineering, and mathematics education for the cyber-workforce through workforce programs and research and development in learning sciences. Such efforts will look to produce rapid progress on changing the balance of diversity in the cyber-workforce, including as part of the CISE support for the NSF INCLUDES investment area. BIO support for SEW (for example, through the National Socio-Environmental Synthesis Center) focuses on advancing the Nation's ability to incorporate and apply biological knowledge to economic development and other issues of societal importance. SEW includes CISE investment in the NSF Research Traineeship (NRT) program that will support the development of bold, new, potentially transformative and scalable models for STEM graduate training focusing on research areas of national priority.

SBE will continue to support SEW by focusing on the nature and dynamics of IT impacts on technical and social systems. SEW also includes SBE funding for cyberinfrastructure related to support of its "Big Three Surveys" (American National Election Studies, the Panel Study of Income Dynamics, and the General

Social Survey), which are national data infrastructures for researchers. Through support for the surveys and the related cyberinfrastructure, SBE supports research that enables examination of societal concerns such as competitiveness, security, economic development, and wellbeing.

NITRD Funding by Program Component Area

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Cyber Security and Information Assurance	$107.31	$110.54	$117.11
Enabling-R&D for High-Capability Computing Systems	133.05	129.81	137.59
High Capability Computing Systems Infrastructure and Applications	188.98	180.42	190.41
High Confidence Software and Systems	83.67	85.82	91.08
Human Computer Interaction and Information Management	187.52	187.38	190.79
Large-Scale Data Management and Analysis	110.69	110.42	115.19
Large Scale Networking	134.81	137.76	147.34
Robotics and Intelligent Systems	43.08	42.99	45.37
Software Design and Productivity	89.08	84.59	86.37
Social, Economic, and Workforce Implications of IT and IT Workforce Development	127.10	126.16	133.16
Total, NITRD	**$1,205.29**	**$1,195.89**	**$1,254.41**

Totals may not add due to rounding.

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Total Funding for USGCRP

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$66.00	$116.11	$125.00
Geosciences	202.09	201.09	201.09
Mathematical and Physical Sciences	13.37	3.50	3.50
Social, Behavioral and Economic Sciences	17.98	17.98	17.98
Total	**$299.44**	**$338.68**	**$347.57**

Totals may not add due to rounding.

Global change encompasses a wide range of planetary- and regional-scale changes in the Earth's natural and human systems. These changes involve atmospheric and ocean circulation and composition, the water cycle, biogeochemical cycles, land and sea ice, biological diversity, marine and terrestrial ecosystem health, resource and land use, urbanization, economic development, and more. The U.S. Global Change Research Program (USGCRP) provides the Nation and the world with the scientific knowledge necessary for understanding and predicting climate change and environmental responses, managing risk, and anticipating opportunities that may result from changes in climate and climate variability. Research conducted through the USGCRP (www.globalchange.gov) builds on the scientific advances of recent decades and deepens our understanding of how the interplay between human and natural systems affects the climate system and how the changing climate impacts those systems. The USGCRP involves thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and new approaches for translating scientific information for use by decision-makers. NSF provides support for a broad range of fundamental research activities that provide the scientific basis for climate-related policy and decisions.

The Earth's climate is determined by highly complex interactions between and among the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere – all significantly influenced by human activities. NSF programs address these components by investing in fundamental discovery that utilizes the full range of intellectual resources of the scientific community, and research infrastructure that provides state-of-the-art capabilities. NSF strongly encourages interdisciplinary approaches, and focuses on fundamental Earth system processes and the consequences of change. High priorities for the agency include: data acquisition and information management activities necessary to support, and disseminate the results of, global change research; the enhancement of models designed to improve our understanding of Earth system processes and of feedbacks between ecosystems and the physical climate; the development of new, innovative Earth observing instruments and networks; the development of advanced analytic research methods; and preparation of a scientific workforce equipped to deal with the complexities of global change. NSF also supports fundamental research on the processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to varying environmental conditions. NSF-supported research on the science of impacts, vulnerability, and resilience as well as the enhancement and development of a range of climate and process models will continue to make an important contribution to climate assessment activities.

FY 2017 Areas of Emphasis

NSF's FY 2017 investment in USGCRP increases by $8.89 million, or 2.6 percent, above the FY 2016 Estimate. The additional investment is associated with the increase in National Ecological Observatory Network (NEON) operations and maintenance (O&M). Because advancing scientific understanding requires a multi-faceted approach, NSF's emphasis areas span multiple USGCRP program component areas. In FY 2017, NSF will engage with other USGCRP agencies on priorities for intra-seasonal to centennial predictability, predictions, and projections; water cycle research; understanding the impacts of global change on the Arctic region and effects on global climate; and fundamental research on actionable science. The major USGCRP foci for NSF include:

Improving our knowledge of Earth's past and present climate variability and change – NSF participates in the Multidisciplinary Earth and Human Understanding, Integrated Modeling, and Integrated Observations program component areas (PCAs) through activities to document and understand long-term climate cycles across the globe, as well as to better understand the natural variability of climate and the processes responsible for climate changes using a range of paleoclimate and instrumental data and modeling approaches. NSF also supports activities to improve our understanding of the frequency and intensity of extreme climate events, particularly wet and dry extremes of the water cycle, their causes, and how those may be manifested in the future. Upgrading and expanding critical environmental observing systems are vital to these efforts.

Improving our understanding of natural and human forces of climate change – NSF supports the Multidisciplinary Earth and Human Understanding PCA through activities spanning a broad range of disciplines and topics that seek to better understand the physical, geological, chemical, biological, and human components of the Earth system and their interactions. Examples of major foci include fundamental research on all aspects of the carbon cycle, the water cycle, atmospheric composition and greenhouse gas processes, marine and terrestrial ecosystems, and ocean and atmospheric circulations that both drive and respond to climate and global change. Human drivers of change include urbanization, population growth, and economic and technological development over a range of temporal scales. NSF has a strong commitment to fostering new interdisciplinary research approaches that allow exploration of the interdependencies across these areas.

Improving our capability to model and predict future conditions and impacts – NSF contributes to the Multidisciplinary Earth and Human Understanding and Integrated Modeling PCAs through research to examine major feedback processes between the climate and natural and human systems and will incorporate these into the next generation Community Earth System Model (CESM). High priority will be given to developing more complete representations of coupled interactive atmospheric chemistry, terrestrial and marine ecosystems, biogeochemical cycling, and middle atmospheric processes. NSF will continue to devote significant resources to advancing climate modeling capabilities from global and centennial to regional and decadal scales. In addition, NSF is encouraging the development of ecosystem and water models at regional scales, as well as models that integrate human system components such as risk, vulnerability, and decision-making.

Assessing the Nation's vulnerability to current and anticipated impacts of climate change – A key focus of the USGCRP is developing better means of assessing the impacts of climate change and the vulnerability and resilience of both human and natural systems to those changes, particularly in highly sensitive regions such as the Arctic. NSF participates in the Multidisciplinary Earth and Human Understanding, Integrated Modeling, Integrated Observations, and the Science of Adaptation and Science to Inform Adaptation Decisions PCAs through support of the basic research that underpins ongoing global change assessment and analysis efforts, particularly in developing the range of models needed for these assessments. NSF will support fundamental research regarding the science of adaptation, defined as the adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. This research ranges from developing the theoretical framework for evaluating adaptation options (and avoiding unintended consequences of adaptation choices) to risk assessment and decision making. NSF will continue interdisciplinary research (including human factors) in water sustainability, biodiversity, ocean acidification, and vulnerable areas, particularly in the rapidly changing Arctic.

Providing climate information and decision support tools – NSF participates in the Science of Adaptation and Science to Inform Adaptation Decisions PCA through basic research on how humans impact climate and other natural systems, how people respond to changing natural conditions, and how human and natural systems engage in complex interactions across multiple spatial, temporal, and organizational scales. Support will continue for basic research on decision making under uncertainty associated with climate change, as well as for developing and testing decision-support tools that can be used by stakeholders to improve their decision making processes.

USGCRP Funding by Program Component Area (PCA)

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Integrated Observations	$50.00	$93.04	$114.00
Multidisciplinary Earth and Human System Understanding	191.54	197.61	185.54
Integrated Modeling	42.15	32.28	32.28
Science of Adaptation and Science to Inform Adaptation Decisions	15.75	15.75	15.75
Total	**$299.44**	**$338.68**	**$347.57**

Totals may not add due to rounding.

PERFORMANCE

NSF PERFORMANCE FRAMEWORK

Introduction

Per the GPRA Modernization Act of 2010, this chapter, together with the Overview, contains basic information about NSF's mission, Strategic Plan, and Agency Priority Goals (APGs), as well as NSF's FY 2017 Annual Performance Plan (APP), FY 2015 Annual Performance Report (APR), and FY 2015 Strategic Objective Progress Update. Information about NSF's performance can also be found on performance.gov, which is updated quarterly with information about APG and Cross-Agency Priority Goal achievement, and on the NSF site in the Performance and Financial Highlights Report.[1]

The FY 2017 Request highlights NSF's priorities for crosscutting investments and organizational efficiencies. NSF's FY 2017 APP underscores the agency's overall priorities through continued strategic monitoring of key program, infrastructure, and management investments. Together with NSF's longstanding performance goal to make timely award decisions, these performance goals provide the foundation of NSF's annual performance assessments. The FY 2017 APP also includes goals that focus on increasing virtual participation in merit review panels, evaluating NSF investments, and fostering an inclusive culture.

Strategic Plan and Strategic Objectives

Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014 – 2018[1] lays out two strategic goals that embody the dual nature of NSF's mission to advance the progress of science while benefitting the nation: *Transform the Frontiers of Science and Engineering,* and *Stimulate Innovation and Address Societal Needs through Research and Education*. A third goal, *Excel as a Federal Science Agency*, directs NSF to hold itself accountable for achieving excellence in carrying out its mission. This goal structure enables NSF to link its investments to longer-term outcomes. To bridge the gap between these strategic goals and measurable outputs, the Strategic Plan establishes a set of strategic objectives for each strategic goal (see next page).

Cross-Agency Priority Goals

NSF contributes to Cross-Agency Priority (CAP) Goals which relate closely to its mission, such as the CAP goal supporting Science, Technology, Engineering, and Mathematics (STEM) Education. Per the GPRA Modernization Act's requirement to address CAP Goals in the agency Strategic Plan, APP, and APR, please refer to www.performance.gov for more on the agency's contributions to those goals and progress, where applicable.

[1] www.nsf.gov/about/performance

2014-2018 NSF Strategic Framework

Strategic Goals	Strategic Objectives
G1: Transform the Frontiers of Science and Engineering	O1: Invest in fundamental research to ensure significant continuing advances across science, engineering, and education. O2: Integrate education and research to support development of a diverse STEM workforce with cutting-edge capabilities. O3: Provide world-class research infrastructure to enable major scientific advances.
G2: Stimulate Innovation and Address Societal Needs through Research and Education	O1: Strengthen the links between fundamental research and societal needs through investments and partnerships. O2: Build the capacity of the Nation to address societal challenges using a suite of formal, informal, and broadly available STEM educational mechanisms.
G3: Excel as a Federal Science Agency	O1: Build an increasingly diverse, engaged, and high-performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital. O2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

STRATEGIC OBJECTIVE PROGRESS UPDATES

In FY 2015, the National Science Foundation conducted seven Strategic Reviews in response to the requirement of the GPRA Modernization Act 2010 Section 1116(f). This section summarizes the status of the actions that NSF plans to take in response to the Strategic Review recommendations.

Strategic Goal 1: Transform the Frontiers of Science and Engineering.
Strategic Objective 1: Invest in fundamental research to ensure significant continuing advances across NSF science, engineering, and education.

The Strategic Review examined mechanisms that NSF can use to overcome the barriers of our traditional, discipline-based organizational structure to advance science at the intersections of disciplines. Available metrics and tools within NSF were used to assess the current status of funding for multidisciplinary research.

1. Are there effective metrics and tools within NSF to evaluate if a proposal or award involves multiple disciplines?

2. Are there sufficient opportunities and effective mechanisms for the research community to submit proposals that involve multiple disciplines, both within and outside of core programs at NSF?

   The Strategic Review used several approaches to investigate whether NSF has effective tools to track multi-disciplinary research. One approach compared different mechanisms of identifying multidisciplinary proposals using proposal and award data from one division. Proposals were classified based on principal investigators (PI) self-classification, program reference codes, the disciplines of the PIs, disciplines of reviewers, co-funding between directorates, and text searchers for the term "interdisciplinary." Estimates of the percentage of proposals that were interdisciplinary using different indicators varied between 12 and 61 for this sample of proposals. Indicators where the PIs classify their own proposals suggest higher percentages of multi-disciplinarity.

   Using the most conservative of these indicators, an analysis was done with a random sample of 20,000 proposals submitted to NSF between CY 2010 and CY 2014. This NSF-wide analysis using the involvement of multiple investigators from different academic departments as the indicator of multi-disciplinarity found that the percentage of proposals submitted that involved multiple divisions varied little over the past five years, and varied only modestly across directorates, with an average of 16 percent. This indicator clearly under-reported the number of multi-disciplinary proposals in programs where proposals were known to be multi-disciplinary. The conclusion from these analyses was that NSF does not currently have appropriate indicators to allow meaningful analyses of multi-disciplinary research.

Opportunities for Action or Improvement

- Develop effective assessment and data tracking methods such that NSF can objectively evaluate research involving multiple disciplines.

Strategic Goal 1: Transform the Frontiers of Science and Engineering.
Strategic Objective 2: Integrate education and research to support development of a diverse STEM workforce with cutting-edge capabilities.

NSF has determined that performance towards this objective is making noteworthy progress.

The Strategic Review examined the strengths and weaknesses of NSF's three primary graduate support mechanisms: research assistantships, fellowships, and traineeships.

1. With its current ratio of 80 percent research assistantships, 15 percent fellowships, and five percent traineeships, is NSF meeting the objectives of G1/O2?

2. What are the strengths and weaknesses of the three primary graduate support mechanisms employed by NSF? What are the ratios of graduate support mechanisms by discipline?

   The Strategic Review used evidence and information provided by external evaluations of NSF programs, National Center for Science & Engineering Statistics (NCSES) published reports, a special tabulation of data from the NCSES Survey of Earned Doctorates, reports from professional associations, and other sources to answer the key analytical questions.

   The primary mechanisms of NSF graduate support are research assistantships (RAs) linked to individual investigator awards (less than five percent are linked to Centers or similar types of programs), fellowships (directly awarded to the graduate student to support their own research), and traineeships (awarded to an institution to support graduate students participating in a particular research program). Recent high-profile reports have stated that the current graduate support system rests too heavily on individual research grants and that a shift to more multiple-year fellowships and traineeships is warranted, returning to a more balanced system of graduate student support similar to that of the 1960s.[1,2] These reports are generally critical of RAs, with statements such as "students on research grants are not necessarily provided with the kinds of programmatic commitment to success, alignment with 21st-century careers, and professional development activities that are components of training grants."[1]

   The sources of evidence that were reviewed suggest that all support mechanisms have been successful in preparing students for the workforce. Although some data exists to understand the impacts of both fellowships and traineeships, and there are some data for center-based RAs, to date there has been no comprehensive data collection across all three graduate support mechanisms to assess the strengths and weaknesses of each approach. To better understand NSF's portfolio of graduate support, the agency should undertake a careful analysis of the relative merits and risks of each support mechanism.

   Numerous factors will complicate this assessment. During their tenure in graduate school, most students are supported by more than one type of funding mechanism that may come from a number of sources and for only part of the academic year.[3] There are also more sources of support than RAs,

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[1] *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security*. Committee on Research Universities; Board on Higher Education and Workforce; Policy and Global Affairs; National Research Council. (2012).
[2] *Advancing Graduate Education in the Chemical Sciences*. Summary Report of an ACS Presidential Commission. American Chemical Society. (2013).
[3] *Special tabulation of data from the Survey of Earned Doctorates.* National Science Foundation, National Center for Science and Engineering Statistics. March 2015.

traineeships, and fellowships. Graduate students can also be supported on teaching assistantships (TA), scholarships, and/ or self-supported through their own resources.[4] Another complication is that the ratios of support mechanisms differ greatly by discipline,[4] though there are few data to determine the primary cause driving these differences, such as whether they are resulting from external constraints, whether they have developed organically in response to the needs of the respective research communities, or a combination of both. Biological sciences have the highest percentage of traineeships (eight percent) relative to all funding sources (including teaching assistants, self-support and “other”) with all other disciplines having less than three percent. The percent of fellowship support is relatively constant between five percent and 14 percent across most disciplines. Psychology and computer science have high percentages of self-support (~50 percent) whereas biological sciences, physical sciences, geoscience, and mathematics have 25 percent or less.

3. Are certain mechanisms of NSF graduate student support more effective in increasing diversity of the STEM workforce?

   Amalgamated data across all disciplines from CY 2009 to CY 2013 show that RAs, fellowships/scholarships, and TAs are the dominant support mechanisms for all racial/ethnic groups, with American Indian/Alaska Native and Black students also having significant funding coming from their personal savings and loans (23 percent to 25 percent).[3] These data also indicate that for all underrepresented groups, fellowships/scholarships are the primary means of support in graduate school (32 percent to 39 percent of doctoral graduates), with RAs (15 percent to 24 percent) and TAs (10 percent to 13 percent) providing less support. Significant differences in the proportion of underrepresented groups across disciplines means that amalgamated demographic data mask graduate support differences among disciplines.[5] Nevertheless, even when analyzing data on fellowship support provided to underrepresented groups by discipline, there is a strong indication that this mechanism is effective in increasing diversity in science and engineering doctoral recipients.[6] Data also show that, since RAs are open to foreign students and other graduate support mechanisms are not, permanent residents (40 percent) and temporary residents (54 percent) rely more heavily on RA support as compared to U.S. citizens (27 percent).[3] Unfortunately, with available data it is not possible to determine the level to which RA support of foreign students is impacting this avenue for supporting underrepresented groups.[3]

   When considering differences in gender, for those disciplines where the number of male to female doctoral candidates is similar or less than 1:2, the distribution of funding across all types of support is nearly equal. For those disciplines where females are a clear minority, the fellowship/scholarship support of female graduate students increases to similar levels as underrepresented groups.[5]

Opportunities for Action or Improvement

- Initiate a data collection using a common, well-documented methodology that will allow comparisons across all three graduate support mechanisms.
- Analyze current approaches that aim to improve graduate student preparedness for entering the workforce beyond traditional roles in academia.
- Understand how awardee institutions position graduate students for future careers and identify NSF programs that contribute to these types of training activities. Support workshops to discuss effective

[4] Tables 35-41, *Survey of Graduate Students and Postdoctorates in Science and Engineering (2012).* National Science Foundation, National Center for Science and Engineering Statistics.
[5] Tables 35-41, *Doctorate Recipients from U.S. Universities: 2012. Special Report NSF 14-305.* National Science Foundation, National Center for Science and Engineering Statistics. 2012. Arlington, VA. Available at www.nsf.gov/statistics/sed/2012/.
[6] *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015.* National Science Foundation, National Center for Science and Engineering Statistics. 2015. Special Report NSF 15-311. Arlington, VA. Available at www.nsf.gov/statistics/wmpd/.

practices for ensuring graduate preparedness. Support pilot programs of new concepts in broadening graduate skills.
- Explore whether additional investments in fellowships targeting increasing diversity would further the goals of G1/O2.

In their cross-cutting assessment of the Strategic Review results, the Performance Improvement Officer (PIO) and Chief Operating Officer (COO) determined that activities initiated in response to these recommendations should be tracked as an Agency Priority Goal.

Strategic Goal 1: Transform the Frontiers of Science and Engineering
Strategic Objective 3: Provide world-class research infrastructure to enable major scientific advances.

Much of today's scientific research is interdisciplinary, data-intensive, and global. Advances often occur through the involvement of large teams working across sites on shared datasets. Cyberinfrastructure, a critical component of research infrastructure, is acting as a catalyst for that change. The purpose of this Strategic Review was to examine NSF activities and roles regarding supporting "Next Generation Research Infrastructure" (NGRI). As a first step, the Strategic Review Team began by defining NGRI.

1. What are some attributes of the Next Generation of Research Infrastructure (NGRI)?

2. How will NGRI change research?

   For the purpose of this review, Research Infrastructure (RI) was defined as any combination of facilities, tools (physical, computational, or analytical), instrumentation, and human capital assembled in support of advancing scientific knowledge, accelerating technology development, enhancing technological and social innovation, and providing training for the next generation of individuals in the STEM fields. RI may be single-sited or distributed; regional, national, or global. Currently RI does not include NSF-designated Centers, which may use RI to support innovative research and education, encourage knowledge transfer, and promote integrative approaches to interdisciplinary activities.

   NGRI is RI that is increasingly:
   - Collaborative: These collaborations can be national or international. Part of the reason for this is to share costs, but it is also due to the increasing complexity of research questions being addressed in STEM fields.
   - Adaptive and Predictive: Researchers use analytical tools and compute cycles on an as-needed basis. This enables rapid data processing and analysis and results in interpretable and just in time findings for end users.
   - Scalable and Integrated: NGRI is linked and expanded through a "network of networks." It is also integrated across physical (e.g., telescope) and cyber (e.g., data stored in cloud) components.
   - Accessible and Transparent: NGRI employs cyber-enabled, graphical human interfaces for data collection, processing and analysis, and, increasingly, operational control of the RI.

   NGRI changes research by providing unprecedented access to ubiquitous distributed computing, which will enable investigators to answer questions they could not before and replicate research more accurately.

3. What are the barriers and opportunities for supporting and catalyzing NGRI at NSF?

   Barriers for moving towards NGRI at NSF:
   - Perceptions: PIs may perceive barriers by NSF or universities to using NSF awards for NGRI resources. A review of NSF policies produced no evidence of intrinsic barriers to charging NGRI (e.g., cloud resources) as a direct cost. Anecdotal evidence suggests that institutions may vary widely in how they classify NGRI costs.
   - Sociological: Not all research communities have a tradition of sharing data or software, or having others control the research infrastructure, nor are there sufficient social and institutional incentives.
   - Resource mismatch compared to other movers in the field: Industry (e.g., Silicon Valley, oil industry, defense) has advanced capabilities and data that move their research ahead of university-based research. NSF's role in this context should be made clear to its community.

- Human capital: Knowledge and understanding. NGRI may present a significant learning curve. Users need help, often through support of other humans, to harness its potential.

Opportunities for Action or Improvement

- Transition to NGRI: Support a workshop to get community input on funding / support gaps in NGRI portfolio to accelerate the transition to NGRI. Several issues to consider include understanding: sustainability of a NGRI investment, including all RI components; how software defined infrastructure concepts and practice can address issues of extensibility of the infrastructure, interoperability with other infrastructures, and sustainability of the infrastructure; and the role of human capital in NGRI.
- NSF policies with respect to NGRI: Review NSF policies that affect use or development of NGRI, and issue an appropriate communication to community.
- Funding gaps: Initiate internal discussions to reevaluate whether there are funding gaps that might affect the support of NGRI projects.

Strategic Goal 2: Stimulate innovation and address societal needs through research and education.
Strategic Objective 1: Strengthen the links between fundamental research and societal needs through investments and partnerships.

The Strategic Review of this goal and objective considered how access to large-scale, NSF-funded data repositories advances national health, prosperity, and welfare, and the critical barriers to making NSF-funded scientific data more broadly available and enduring. It also examined whether existing NSF mechanisms are sufficient to inform relevant communities about data repositories.

1. How does access to NSF-funded data repositories advance national health, prosperity, and welfare?

   NSF, along with other federal agencies, has funded hundreds of data repositories. Efforts redoubled in 2013 in response to OSTP's call to make publically-funded research more available. Three ways repositories contribute to societal needs are:

   - Access to high quality data encourages innovation by lowering the technical and resource barriers to innovation and engaging a global research community.
   - Expanded access to enduring, quality data expands the accepted scholarly record to include the preservation of the observational, experimental, and computational data that is rapidly accumulating in every field of science.
   - Increased access to data leverages the public research investments that result in data generated by surveys, mobile and embedded systems, sensors, observing systems, scientific instruments, experiments, simulations, evaluations and analyses.

2. What are some of the critical barriers to making NSF-funded scientific data more broadly available and enduring?

   One of the barriers is that infrastructure is limited. There are few existing long-term, deep archives that are readily suitable for data deposit. Tools for search and discovery, and pathways for data transfer to repositories at project end need to be improved. There is also the need for more consistent data citation standards and the use of persistent data identifiers.

   Another barrier is that roles and responsibilities are still evolving and this leads to uncertainty. This is true in the research community regarding data management practices, dissemination, and attribution/re-use. At NSF, roles regarding data policies in proposal review and portfolio management are evolving. Among federal agencies, roles for coordination, planning, and assessing data efforts are also changing.

   Financial resources are needed to address disciplinary/strategic data repository needs, to ensure the sustainability of major NSF-funded community data facilities, and to enable "long tail" continued use of data repositories.

3. What are the mechanisms in place within NSF to inform relevant communities about data repositories, and are they sufficient?

   Several, disparate repository efforts are found across the agency in various programs. The Public Access Plan[7] provides high-level guidance and clearly states NSF's firm commitment to data access and preservation. The Cyberinfrastructure Coordinating and Leadership Group (CLG) is exploring

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[7] www.nsf.gov/pubs/2015/nsf15052/nsf15052.pdf

current efforts in data and cyberinfrastructure priorities of the various directorates, and relevant gaps and opportunities.

Opportunities for Action or Improvement

- Refine data management guidance and practices (see, e.g., NSF's Public Access Plan, Sections 7.2.2-7.2.3, 7.3.2, 7.4.2);
- Identify and expand use of partnerships to support creation and sustainability of data management resources.

Strategic Goal 2: Stimulate innovation and address societal needs through research and education.
Strategic Objective 2: Build the capacity of the Nation to address societal challenges using a suite of formal, informal, and broadly available STEM educational mechanisms.

The Strategic Review examined the role that Public Participation in STEM Research (PPSR) can play in advancing science and engineering and increasing the participation of the U.S. population in science and engineering broadly. PPSR is an overarching category for projects that involve partnerships between professional scientists and amateurs and always involves the public's participation in at least some aspects of genuine STEM research. Activities known as "citizen science" and "crowdsourcing science" are both included. The field of PPSR has evolved rapidly from a focus simply on data collection toward a more collaborative enterprise, where participants are increasingly involved in more aspects of the research process.

1. How is 'Public Participation in STEM Research' (PPSR) defined?

2. How can NSF's investments in PPSR be characterized?

3. What cutting-edge investments might NSF make to advance PPSR?

   Citizen science has taken place for centuries in a variety of fields (e.g., Christmas Bird Count, lighthouse weather data, and astronomical observations) but has grown significantly in the past decade, in part due to new technological tools. Similarly, crowdsourcing science refers to processes in which open calls are made for voluntary contributions to STEM problem-solving. These calls are typically either to a non-specified group of individuals ("the crowd") or to individuals with specific expertise, thus leveraging the skills and knowledge of many (e.g., Foldit[8], EyeWire[9]).

   The motivation for PPSR, whether citizen science or crowdsourcing science, may be derived from community concerns or may be scientist-led. NSF has chosen to follow the field in calling these activities PPSR in order to clarify that the focus is on participation in STEM, and should not be confused with an activity that focuses on any individual's (or group's) nationality. In addition, NSF is using "STEM" in lieu of "Scientific" (i.e., "Public Participation in STEM Research") to ensure recognition of this approach in all areas of science and engineering.

   PPSR projects have both scientific and educational value. Without public participants and their contributions, some research would not be practical or even possible (e.g., projects requiring data collection from many geographical locations or over long periods of time, or projects requiring analysis of large sets of visual or numeric data). Moreover, PPSR provides opportunities for people of all genders, races, ethnicities, ages, and geographic locations to learn how STEM research is conducted and to engage in it directly. The level of public involvement varies from being contributory (e.g., collecting and recording data) to collaborative (e.g., analyzing samples and discussing results) to co-created (i.e., in which the public might be involved in all phases of the scientific process from defining the question for investigation, to experimenting, analyzing, and reporting results).

   An analysis of NSF awards active in October 2014, identified 187 projects that included elements of PPSR. Approximately 50 new awards have been funded each year from FY 2012 to FY 2014. Thematically, investments in all disciplines aimed to increase data quality. Development of mobile technologies for sensing and data collection was an interest primarily centered in awards from ENG,

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[8] https://fold.it/portal/
[9] http://blog.eyewire.org/about/

CISE, BIO, EHR, and GEO. Not surprisingly, collecting data over large geographic and/or temporal scales was a theme in BIO and GEO awards, whereas understanding how PPSR engages people surfaced as a theme in SBE and EHR awards. A minority of awards contained aspects related to security and privacy (particularly in CISE) or enhancing and measuring learning (particularly in EHR).

Through its awards, NSF has played a seminal role in supporting the expanding field of PPSR in terms of science, technology, and learning. For example, building on NSF investments, the growing community of practice has formed a Citizen Science Association and a new *Citizen Science: Theory and Practice* journal. To continue to advance PPSR, NSF should consider investments in the following:

- Support the Growing PPSR Community of Practice. The field of PPSR has evolved rapidly from a focus simply on data collection toward a more collaborative enterprise, where participants are increasingly involved in more aspects of the research process. NSF should consider investing in efforts to support this community in terms of recruitment, networking, training, data reporting, authorship, and assessment.

- Advance the Technologies and Tools of PPSR. To continue to promote greater levels of public involvement in PPSR, the development of more user-friendly, robust, and affordable sensors for STEM research could be promoted. As more public participants become collaborators in scientific research, many issues related to networking, data management and access, data quality, and crowd-sourced analytics, as well as their scale-up, would need to be addressed.

- Investigate the Contributions of PPSR to Learning. NSF broke ground by funding projects that recognized learning as a key outcome of PPSR projects. The learning aspect of PPSR warrants additional study to understand the demographics and motivations of participants, the extent and nature of STEM learning and engagement, and the most effective strategies for broadening participation in STEM through PPSR experiences.

- Assess the Potential of PPSR to Enable New Fields of Discovery Research._With the opportunity to reach more people and therefore collect and analyze data sets more extensively than possible through the efforts of scientists alone, PPSR may go beyond simply enhancing our ability to do traditional STEM better. PPSR enables us to pursue entirely new avenues of research that can only be achieved through public-scientist collaborations. The different cultural perspectives and habits of mind that public participants can bring to bear on the interpretation of data may also open new avenues of research. This potential is worth exploring.

Opportunities for Action or Improvement
NSF should take the next steps to promote theoretical and empirical research leading toward a 'Science of PPSR.' Analogous to developments in learning in the past, PPSR is moving from a type of activity to be supported to a way of doing research and learning that needs to be understood. The steps in this direction, in priority order, are to:

- Support a workshop on PPSR learning & broadening participation
- Encourage, through existing programs, advances in sensors and communication/data management infrastructure for PPSR.

In their cross-cutting assessment of the Strategic Review results, the PIO and COO determined that activities initiated in response to these recommendations should be tracked as an Agency Priority Goal.

Strategic Goal 3: Excel as a Scientific Federal Agency.
Strategic Objective 1: Build an increasingly diverse, engaged, and high performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital.

Program directors (PDs), including permanent and rotator staff, are the largest and highest-turnover segment of NSF's workforce. The Strategic Review of this goal and objective considered the changes in the PD job duties and workforce over the last 15 years and examined factors impacting recruitment, selection, and retention of PDs. The Strategic Review utilized an array of qualitative and quantitative evidence to support the key findings and recommended actions summarized below.

1. What qualities does NSF seek in program directors?

   Although each directorate seeks a slightly different combination of skills when recruiting program directors, most include skillsets that fall into three categories: 1) technical expertise, 2) management skills (the ability to get things done), and 3) a collaborative mindset. The team noted the increasing importance of non-technical skills in the timeframe considered.

2. How has the program director job changed over the past 15 years?

   Recruitment and retention of program directors is correlated to the changes in the program director job duties over the past 15 years. These changes include increasingly large and complex workloads without proportional staffing changes (proposals up 65 percent, staffing up only 20 percent), use of increasingly complex electronic systems and communications, travel policies, salary and performance award policies, multi-directorate solicitations, and reduced participation in the Independent Research Development (IR/D) program. In addition, the interrelationship between the delays in receiving appropriations, GPRA dwell time goals, time-consuming compliance checking, and end-of-year close-out pressures add to workload concerns.

3. What are the factors impacting recruitment, selection, and retention of a high-performing program director workforce?

   Nineteen percent of NSF's STEM workforce was eligible to retire at the end of FY 2014, with eligibility projected to grow to 32 percent by FY 2018. It is expected that a significant fraction of these people will choose to retire at the time of or prior to NSF's move to Alexandria. In the 2014 FEVS results, the STEM workforce reported having unreasonable workload levels more often than any other NSF job family. The team identified a range of professional, personal, and environmental/logistical factors that affect recruitment and retention in both positive and negative ways. The time it takes to recruit program directors, particularly rotators, has increased significantly in recent years, making it particularly important to prioritize actions NSF can take to strengthen our ability to recruit and retain staff.

   Opportunities for Action or Improvement

   - Develop mechanisms to better manage individual workload and minimize disparities in workload.
   - Implement exit and stay interviews as necessary to identify trends.

Strategic Goal 3: Excel as a Scientific Federal Agency.
Strategic Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

NSF has determined that this objective should be a focus area for improvement.

The Strategic Review used several sources of evidence to address the key analytical questions, including previous customer satisfaction surveys, evaluation reports, administrative data, a review of customer service performance measures at other agencies (NIH, USDA, NASA, DOE, Education, VA), a panel discussion with the National Science Board, and a small sample of survey responses from program directors and principal investigators (PI) to questions about customer service.

The strategic review team considered the advantages and disadvantages of dwell time versus other metrics of customer service. Three characteristics of customer service were determined to be important: Quality, transparency, and timeliness. The current dwell time goal addresses only timeliness of providing review feedback to the customer. It does not encourage or incentivize other aspects of customer service, such as providing specific post-review feedback to PIs. As part of the Strategic Review, NSF conducted a panel discussion with members of the National Science Board, where members encouraged NSF to consider quality as well as timeliness in our customer service goals. One National Science Board member commented that "speed without quality is not a good standard to have, as one can do a bad job quickly."

The Strategic Review used internal data to assess the impacts on work processes to determine whether the dwell-time goal has unintended consequences on workload or on the review process. The evidence demonstrated that the timing of budget appropriation and current plan implementation does not impact dwell time. However, the dwell time goal encourages staff to process declines before awards because they can be done faster, which creates conflict with award leveling.

The data also show that since 2010 NSF is utilizing fewer total reviewers and fewer new reviewers for more proposals, thereby including less of the community in our review process. This decrease could be due to time limitations to recruit reviewers or the increasing change from ad hoc to panel review. It is difficult to disambiguate the effects of the increasing number of proposals generally as opposed to the specific pressure of a dwell time goal.

The strategic review determined that additional feedback from customers is needed to assess which aspects of customer service should be the targets of a new customer service goal. NSF fielded a survey of NSF PIs and reviewers that included questions about customer service. The forthcoming results of this survey will be used to identify targets for a new customer service goal focused on quality.

Opportunities for Action or Improvement

- Develop and pilot ideas for additional customer service goals based on the results of the customer service survey and analysis of PI behavior.

Status of Actions Recommended in FY 2015 Strategic Reviews

Goal/ Objective	**Opportunities for Action or Improvement**	**Status**	**Lead Org/s**
G1/O1	Develop effective data tracking methods for research involving multiple disciplines.	In FY 2016, the Office of Integrative Activities, Evaluation and Assessment Capability (EAC) office will lead a working group charged with the task of recommending specific mechanisms to improve NSF's ability to track interdisciplinary research. This task will entail developing an operational definition of interdisciplinary research, and an inventory of interdisciplinary activities across NSF. Portfolio analysis tools will be used to confirm or revise the definition. Recommendations will be made based on definitions. In FY 2017, the working group will implement findings and decisions from FY 2016.	OIA/EAC
G1/O2	Initiate a data collection using a common, well-documented methodology across all three graduate support mechanisms.	The NSF-wide Graduate Education Strategic Planning Group will assemble available national data about various modes of support of graduate students by research fields. There are significant data gathered annually on GRFP participants; EAC will review the possibility of gathering similar data on other NSF-funded graduate students. The Graduate Education Strategic Planning Group, in collaboration with EAC and NCSES, will make recommendations about needed national and NSF-specific data collection for consideration by NSF leadership.	EHR OIA/EAC
	Support pilot programs of new concepts in broadening graduate skills. Analyze current approaches that aim to improve graduate student preparedness for entering the workforce beyond traditional roles in academia. Understand how awardee institutions position graduate students for future careers and identify NSF programs that contribute to these types of training activities.	New pilot programs to broaden graduate skills will be part of NSF's Agency Priority Goal to "Improve STEM graduate student preparedness for entering the workforce." A portfolio analysis of proposals submitted to the pilot programs will identify promising approaches and inform the possible scale-up of programs in FY 2017 and beyond. See the Annual Performance Plan for a full description of the Agency Priority Goal.	GEO ENG
	Review the appropriate "package" of support for	These opportunities for action or improvement are under consideration by the	EHR

Goal/ Objective	Opportunities for Action or Improvement	Status	Lead Org/s
	students during their time in graduate school. Explore whether additional investments in fellowships targeting increasing diversity would further the goals of G1/O2.	NSF-wide Graduate Education Strategic Planning Group	
G1/O3	Hold workshops to get community input on funding/ support gaps in NGRI portfolio to accelerate the transition to NGRI.	NSF will add sessions to planned community workshops (as appropriate) to get input on accelerating the transition to NGRI. Focus areas may include better defining NGRI, maximal leverage/sharing of cyber-infrastructure (CI) capabilities, possible funding gaps, restrictive practices, life-cycle management of both existing infrastructure and NGRI, and the important role of human capital. Potential near-term venues include the annual Large Facilities Workshop planned for May 2016 and a separate joint CI/Large Facilities Workshop in FY 2016.	CISE MPS BFA/LFO
	Review NSF policies that affect use or development of NGRI, and issue an appropriate communication to community.	Prior to the 2016 Large Facilities Workshop, NSF will hold a Program Officer's Forum to discuss policies that may be hindering development of NGRI. This input will help inform the community workshop sessions.	CISE MPS BFA/LFO
	Initiate internal discussions to reevaluate whether there are funding gaps that might affect the support of NGRI projects.	NSF is evaluating options for improved facilities portfolio management in order to identify funding opportunities to better support NGRI planning and implementation	BFA/BD BFA/LFO
G2/O1	Refine data management guidance and practices.	NSF will implement, as outlined in publication NSF 15-52, "NSF's Public Access Plan: Today's Data, Tomorrow's Discoveries."	CISE OIRM (CIO)
	Identify and expand partnerships to support creation and sustainability of data management resources.	The Cyberinfrastructure Coordinating and Leadership Group (CLG) has begun to address the issue of sustainability of data management resources. A new activity planned for FY 2017, Data for Scientific Discovery and Action (D4SDA), has goals to stimulate "community engagement to develop governance structures and management of data life cycle and to grow community's use of infrastructure" and to develop "collaborations and partnerships." The CLG will also hold an internal workshop to bring together different parts of the foundation to share information, with the goal of capturing different models for how	CISE (CLG)

Goal/ Objective	Opportunities for Action or Improvement	Status	Lead Org/s
		communities are dealing with sustainability of data resources. The efforts of the CLG will align with NSF's efforts on public access. Additional information can be found in the CIF21 Roadmap.	
	Support a workshop on PPSR learning & broadening participation. Encourage, through existing programs, advances in sensors and communication/ data management infrastructure for PPSR.	This opportunity for action or improvement will be addressed through the Agency Priority Goal on PPSR. Build the capacity of the Nation to solve research challenges and improve learning by investing strategically in citizen science, crowdsourcing, and other forms of public participation in science, technology, engineering, and mathematics (STEM). See the Annual Performance Plan for a full description of the Agency Priority Goal.	EHR CISE
G2/O1	Implement regular exit and stay interviews.	NSF is currently developing exit and engagement (stay) interview templates along with standard operating procedures for their implementation. Pilots are expected to begin in early FY 2016.	OIRM
G3/O1	Develop mechanisms to better manage individual workload and minimize disparities in workload to improve the retention of Program Directors.	NSF is exploring was to combine information contained in what are currently separate business intelligence systems related to personnel and program management in order to enhance the current workload model for transactional activities. In addition, NSF is exploring how to include information on activities going beyond the transaction-based activities of the current model.	OIRM
	In FY 2016 develop ideas for new customer service goals based on the results of the upcoming customer service survey.	PI responses to questions about their satisfaction with the timeliness and quality of feedback received from NSF will be used to develop additional customer service performance goals. Potential performance goals will be assessed internally to determine the effect on Program Officer workload prior to a decision regarding possible implementation in FY 2018.	BFA OIRM
G3/O2	In FY 2016 develop ideas for new customer service goals based on the results of the upcoming customer service survey.	PI responses to questions about their satisfaction with the timeliness and quality of feedback received from NSF will be used to develop additional customer service performance goals. Potential performance goals will be assessed internally to determine the effect on program officer workload prior to a decision regarding possible implementation in FY 2018.	BFA OIRM

Recommendations from FY 2014 Strategic Reviews that were completed in FY 2015

Strategic Goal/Obj.	Action	Status of Proposed Action	Lead Org/s
G1/01	Reinforce NSF commitment to IDR in internal and external communications to ensure that IDR is viewed positively.	A DCL was issued to reinforce NSF's commitment to IDR.	OD/OIA
G1/01	Assess the impact of PTR funding across NSF through formal studies.	An evaluation of the INSPIRE program contracted by the Evaluation and Assessment Capability (EAC) was expanded to include a comparison of mechanism to fund IDR and PTR.	OD/OIA
G1/01	Assess PTR mechanisms, such as EAGERs and Ideas Labs, which have been used for several years, but have not been assessed yet. A formative evaluation for INSPIRE has been initiated.		
G1/01	Institute an external retrospective study that compares the predicted transformative potential (from reviews and panel summaries) of awards and declines from 5-10 years ago with the actual outcomes.		
G1/02	Convene a symposium on "Integration of Research and Education" to synthesize evidence relevant to the proposed theories of change, identify gaps in understanding, and develop a research agenda to determine ways to most effectively develop both a diverse and excellent workforce.	A workshop was held in April of 2015 to explore the multiple interpretations of the phrase "integration of education and research." The Division of Undergraduate Education will use the recommendations to inform future actions.	EHR/DUE GEO

Strategic Goal/Obj.	Action	Status of Proposed Action	Lead Org/s
G1/03	Evaluate the current and future resource and structural needs within the Foundation to successfully support its facilities. The increasing level of complexity of the facility programs that the NSF funds, as well as the recognition that the Foundation is changing the overall planning for the lifecycle of facilities, point to the time being ripe for the Foundation to address this issue.	The Large Facilities Manual (LFM) has been completely revised to include clearer policies and procedures on contingency, cost analysis and management fee. The Large Facilities Working Group (LFWG) has been fully implemented and played a pivotal role in revision of the LFM. The Integrated Project Team (IPT) approach has been implemented on four projects in construction, one in design as a pilot, and one in operations. Both the LFWG and the IPT approach have been codified in the revised LFM. The LFO has also recently added two additional staff to support increased oversight of Large Facilities.	BFA/LFO
G2/01	Study new and emerging IP practices, and disseminate the results in order to stimulate innovative thinking in IP management.	In FY 2015 NSF co-sponsored a national town hall meeting with the University-Industry Demonstration Partnership on February 26, 2015.	ENG
G2/01	Convene a workshop to brainstorm how to further cultivate innovative thinking and entrepreneurship among students (building on NSF I-Corps™ successes), and what new models of education are emerging or will be appropriate. The ultimate goal is to cultivate industry-relevant skills and the mentality for technology commercialization among students.	NSF sponsored the National Innovation Network (NIN) workshop in June 2-3, 2015. The workshop included a review of the training, resource/tool development, and research efforts of the I-Corps™ Nodes and Sites to identify and develop promising ideas that can generate value and enhance the innovation capacity and ecosystem of the Nation.	ENG
G2/02	Develop and implement data collection on impact metrics with respect to NSF-developed communications.	Metrics were identified and are being collected on a quarterly basis.	OLPA
G3/01	Identify indicators of progress for a "diverse, engaged, and high performing" workforce and the data sources for establishing baselines and measuring progress.	Indicators were identified and baselines established.	OIRM/HRM

Strategic Goal/Obj.	Action	Status of Proposed Action	Lead Org/s
G3/01	Structure the developing human capital dashboard to make data and information on key indicators accessible to decision makers at a glance and enable deep dives for targeted action.	The first phase of Strategic Human Capital Management (SHCM) Dashboard has been completed; focus areas include retention and loss rates, career paths and development opportunities, hiring patterns and time to hire, and workload; indicators include a combination of workforce profile data from HR systems and data from the Federal Employee Viewpoint Survey (FEVS); Dashboard is now being expanded from a few basic indicators to a broader knowledge system.	OIRM/HRM
G3/01	Use short "pulse" surveys, focus groups, and other mechanisms to understand what it will take to retain at least 70 percent of NSF's current permanent staff through the transition to Alexandria. Prioritize actions and strategies based on the result.	A number of outreach activities identified strategies focused on workforce planning, recruitment, hiring and retention, action planning for employee engagement, diversity and inclusion, and improvements to performance management systems. The FY 2015 Strategic Review for this objective focused on Program Officer recruitment and retention as a follow-up.	OIRM/HRM
G3/01	Create explicit strategies to replace both the rotator population and retirements anticipated between now and 2016.		

Recommendations from FY 2014 Strategic Reviews that are expected to be completed in FY 2016

Strategic Goal/Obj	Action	Lead Org/s
G1/01	Modify NSF e-business systems and processes to allow for IDR complexity.	OD/OIA CPIC OIRM/DIS
G2/02	Assess the quality of the proposal responses to the revised elements of the broader impacts criterion.	OD/OIA
G2/02	Consider strategies to facilitate coordinated broader impacts efforts above the project level.	EHR(IUSE working group)
G3/01	Create the underlying logic models for how strategies related to recruitment, training, leadership, and human capital management influence building an increasingly diverse, engaged, and high performing workforce, with particular attention to inter-dependencies of strategies and outcomes.	OIRM/HRM
G3/02	Implement a cultural assessment, using evidence-based survey tools, with the goal of identifying our organizational strengths and opportunities for improvement. The results of the cultural assessment will be reviewed in the context of the results of the Federal Employee Viewpoint Survey to describe actionable objectives towards agency excellence.	SBE BFA OIRM

FY 2015 ANNUAL PERFORMANCE REPORT

Each fiscal year the National Science Foundation (NSF) is required to prepare three reports to provide financial management and program performance information: the Annual Performance Report (APR), the Agency Financial Report (AFR), and the Performance and Financial Highlights Report. This report, the APR, includes the results of NSF's FY 2015 performance goals, including the agency priority goals (APGs), related to the Government Performance and Results Act of 1993 (GPRA) and the GPRA Modernization Act of 2010. All three reports are posted annually on the Budget and Performance page of the NSF web site (www.nsf.gov/about/performance/).

FY 2015 was the first full year of the implementation of NSF's Strategic Plan, *Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014-2018*. In FY 2015, NSF tracked progress toward its three strategic goals, using ten performance goals, three of which are APGs. Based on results through Q4 of FY 2015, four of the ten goals fully achieved their targets in FY 2015 and six did not achieve one or more targets. Below is a tabular overview.

Goal ID	Performance Goals	FY 2015 Result
1	APG: Public Access Priority Goal	Not Achieved
2	APG: Data Science Priority Goal	Achieved
3	APG: Level Workload Priority Goal	Not Achieved
4	Key Program Investments	Achieved
5	Research Infrastructure Investments	Not Achieved
6	Evaluate NSF Investments	Not Achieved
7	Diversity and Inclusion	Not Achieved
8	Evidence-Based Management	Achieved
9	Timely Award Decisions	Achieved
10	Proposal Review Efficiency	Not Achieved

This section presents results for each performance goal in its strategic context, with reference to strategic goals, objectives, and targets from NSF's 2014-2018 Strategic Plan. Multiple years of trend data are available for NSF's longest-standing quantitative performance measures, time to decision (Goal 9) and the monitoring of construction projects (Goal 5). Other performance goals monitor progress towards multiyear goals, such as implementation of a new process or program (Goals 6 and 10) or an operational improvement (Goals 7 and 8).

Goal 1, Agency Priority Goal: Ensure Public Access to Publications
Lead Organization: Office of the Director.

Strategic Alignment

- Strategic Goal 1: Transform the Frontiers of Science and Engineering, Objective 3: Provide world-class research infrastructure to enable major scientific advances.
- Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education, Objective 1: Strengthen the links between fundamental research and societal needs through investments and partnerships.
- Strategic Goal 3: Excel as a Federal Science Agency, Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2014-2015	Ensure Public Access to Publications	By September 30, 2015, NSF-funded investigators will be able to deposit versions of their peer-reviewed articles in a repository to make them available to the public within one year of publication.	Not achieved.

Discussion
Activities and achievements for this goal fall into several categories: development of the manuscript submission system, changes to internal NSF systems, and outreach. For more information, see www.performance.gov/content/ensure-public-access-publications.

- Development of manuscript submission system. The system was delayed several weeks due to issues with obtaining security certificates. Other components (e.g., interface design, metadata definition and display, negotiation of external agreements) were not delayed. In June 2014, NSF entered into a memorandum of agreement for external repository services and finalized an interagency agreement with the Department of Energy, Office of Scientific and Technical Information (DOE/OSTI) to support system development. Parts of the NSF Public Access Repository (NSF-PAR) system were released in mid-November. The full roll-out began on November 20, 2015, and all components (public search, manuscript upload, and integration in internal award management systems) were functional by December 1, 2015. There are currently more than 12,000 records publicly available, and NSF is piloting the end-to-end author/program officer functionality. NSF and DOE will continue to monitor performance.
- Changes to internal systems. NSF has largely completed the requirements for the interfaces between the external and internal systems and has drafted user interfaces for primary investigators (PIs) and program officers (POs), based on earlier testing and additional user requirements studies. NSF made satisfactory progress in FY 2014 in identifying proposed changes to internal systems to accommodate system integration. The testing of the internal/external system integration was completed in FY 2014.
- Outreach. The NSF Public Access Plan (15-52) was released on March 18, 2015 together with a public website.[1] NSF made satisfactory progress in undertaking outreach and discussions with different stakeholder groups, other federal agencies, and possible public/private partners. NSF will continue to reach out to concerned stakeholder groups and accept comments on the plan

Explanation of Unmet Goal
This goal was not achieved in FY 2015 but was achieved December 1, 2015 (Q1 of FY 2016). The system was delayed several weeks due to issues with obtaining security certificates. Other components (e.g., interface design, metadata definition and display, negotiation of external agreements) were not delayed.

[1] www.nsf.gov/news/special_reports/public_access/

<u>Goal 2, Agency Priority Goal: Increase Data Scientists and Data Infrastructure</u>
Lead Organizations: Directorate for Computer and Information Sciences and Engineering, Directorate for Education and Human Resources.

Strategic Alignment:
- Strategic Goal 1: Transform the Frontiers of Science and Engineering, Objective 3: Provide world-class research infrastructure to enable major scientific advances.
- Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education, Objective 1: Strengthen the links between fundamental research and societal needs through investments and partnerships.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2014-2015	Increase Data Scientists and Data Infrastructure	By September 30, 2015, implement mechanisms to support the training and workforce development of future data scientists; increase the number of multi-stakeholder partnerships to address the Nation’s big-data challenges; and increase investments in current and future data infrastructure extending data–intensive science into more research communities.	Achieved.

Discussion
Activities and achievements for this goal fall into several categories: support for human capital development, partnerships, and infrastructure.[2]

- <u>Human Capital Development.</u> NSF has successfully inserted language emphasizing the education and training of data scientists in 18 solicitations. In the two-year period of this goal, NSF funded a number of workshops for the community:
  - NAS Workshop: Training Students to Extract Value from Big Data, April 2014.[3]
  - Advancing Data-Intensive Research in Education, June 2015.[4]
  - Graduate Data Science Workshop, August 2015.[5]
- <u>Partnerships</u>. Four Big Data Innovation Hubs were funded in FY 2015 to support partnerships that strive to achieve common big data goals that would not be possible to achieve alone.
- <u>Infrastructure</u>. In an effort to measure the number of communities/organizations/ecosystems that use data infrastructure and tools for their research and development (R&D) activities, NSF determined data intensiveness of NSF communities by monitoring the use of data-intensive high performance computing resources though Extreme Science and Engineering Discovery Environment (XSEDE). Compared to FY 2013, FY 2015 usage of XSEDE’s data intensive resources rose by 30 percent. The number of scientific disciplines using XSEDE rose by 25 percent (from 28 to 35 disciplines).

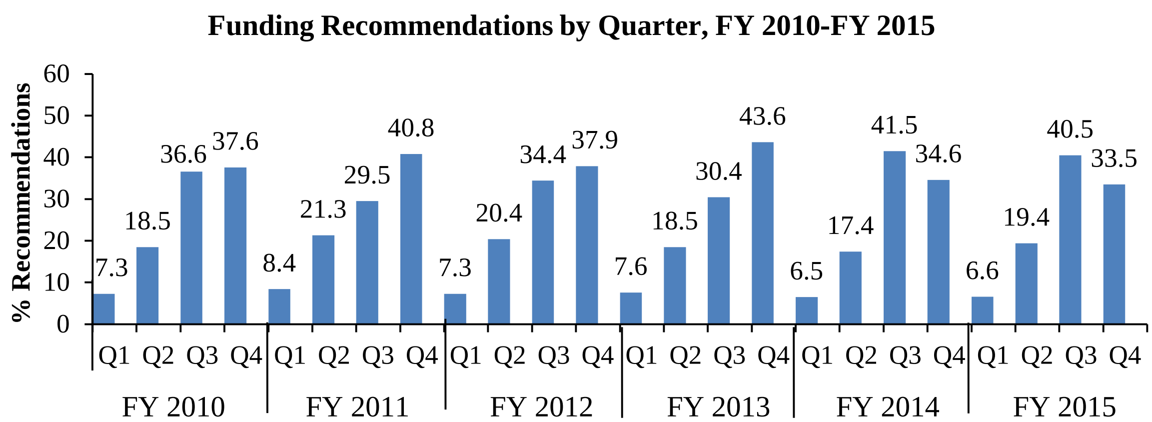
[2] For more information, see www.performance.gov/content/increase-nation’s-data-science-capacity.
[3] www.nap.edu/read/18981/chapter/1
[4] http://cra.org/events/workshop-2-advancing-data-intensive-research-in-education/
[5] http://depts.washington.edu/dswkshp/

Goal 3, Agency Priority Goal: Optimize the Award Process to Level Workload
Lead Organization: Office of Budget, Finance, and Award Management.

Strategic Alignment:

- Strategic Goal 3: Excel as a Federal Science Agency, Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2014-2015	Optimize the Award Process to Level Workload	By September 30, 2015, meet targets to level distribution of awards across the fiscal year and subsequently improve awardee capacity to effectively manage research funding. Q1 target: 20 percent of funded actions (baseline=8 percent) Q2 target: 35 percent of funded actions (baseline=20 percent) Q3 target: 25 percent of funded actions (baseline=33 percent) Q4 target: 20 percent of funded actions (baseline=40 percent)	Not achieved.
Actual Results for Preceding Fiscal Years			



Discussion
For more information on this goal, see www.performance.gov/content/optimize-award-process-level-workload.

NSF typically awards a large fraction of its nearly 20,000 funded grant actions in Q4 due to the fact that almost 75 percent of proposals and funding requests are recommended for award during the last half of the fiscal year. Issuing such a high volume of awards in a compressed time period during the end of the fiscal year not only strains NSF's workforce, as well as other resources such as IT business systems and space for conducting review panels, but also increases risk and places added stress on awardee capabilities coinciding with these peak workload periods. This goal was set to promote strategies that address calendar management, operating procedures, and potential IT improvements, with the goal of mitigating the negative impacts of the current imbalanced award distribution for both NSF and the Nation's scientific research community.

The FY 2014 activities towards this goal were focused on establishing implementation teams for each directorate and piloting approaches that may provide novel and/or innovative solutions to leveling proposal and award workload across the fiscal year. The FY 2014 data (above, with trend information for context) show that NSF began to see a shift in its annual workload of awards recommended for funding into Q3 of FY 2014. This was due to two major factors unique to FY 2014: the lapse in funding authority in Q1, which halted receipt and delayed review of proposals NSF-wide, and preparations for transition to a new financial system in Q4, which went live in early FY 2015. The changes to close-out processes required by the financial system transition resulted in movement of more than five percent of recommended awards out of Q4.

Explanation of Unmet Goal

This goal was not achieved in FY 2015. While there was a slight shift of actions into Q1 and Q2 and out of Q4 compared to FY 2014, overall levels were in line with historical trends. NSF has learned that such changes would take more than two years.

In FY 2016 and beyond, NSF will apply lessons learned from the goal to continue efforts within the agency to level workload. For example, strategic decisions to move deadlines for specific high-volume programs can have significant effects in moving actions across quarters. Future efforts in this area will focus on such strategically chosen actions likely to have small impact on NSF operations as a whole but large impact on awards processing.

Goal 4. Key Program Investments
Lead Organization: Office of Budget, Finance, and Award Management.

Strategic Alignment:
- Strategic Goal 1: Transform the Frontiers of Science and Engineering, All Objectives
- Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education, All Objectives

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015	Meet critical targets for key program investments.	Monitor the progress of Cognitive Science and Neuroscience, CEMMSS, CIF21, SaTC, and SEES using a common set of milestones and indicators.	Achieved (five of five programs monitored).
Actual Results for Preceding Fiscal Years			
2014 (new goal)	Meet critical targets for key FY 2014 program investments.	Monitor the progress of CEMMSS, CIF21, I-Corps™, INSPIRE, SaTC, and SEES using a common set of milestones and indicators.	Not achieved (four of six programs monitored).

Discussion
NSF instituted the Key Program Investments goal in FY 2014 to track the interim progress of major investments towards their long-term goals. Each year, NSF highlights a number of cross-agency investments in its Budget Request to Congress. Although the overall impact of these investments might not be measurable for many years, tracking near-term indicators of progress can help the agency make formative changes or course corrections.

In FY 2015, NSF successfully monitored the progress of five NSF-wide investments (Understanding the Brain, CEMMSS, CIF21, SaTC, and SEES) using a common set of indicators and reviewed the results with senior leaders. The indicators that NSF chose to measure were programmatic inputs and outputs that can provide valuable signals to managers and leaders about a program's health, such as whether the program is being administered as planned or whether the program is generating enough interest from the community. The following were tracked quarterly in FY 2015:
- Input indicator: progress towards the investment's funding level target.
- Output indicators: solicitations issued, proposals received, awards made.
- Investment-specific activities: defined by each investment in its roadmap, this can include PI meetings, Ideas Labs, workshops, and evaluation contract deliverables.

These measures enabled managers and leaders to quickly gauge the status of a program's implementation, interest from the scientific community, whether the review process resulted in awards in a timely manner, and whether the program has met its internal goals for short-term outcomes. Tracking these measures over time provided managers and leaders with the opportunity to assess whether mid-course corrections were needed to improve program management and/or the overall direction of the investment.

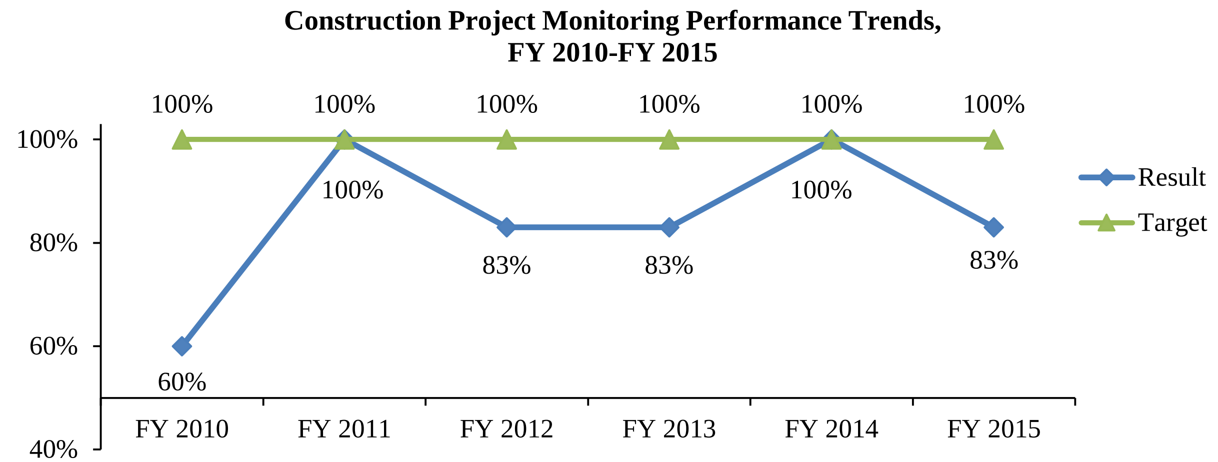
In FY 2016, three programs will be monitored including Understanding the Brain and two new programs, NSF INCLUDES and INFEWS. Monitoring of the four other FY 2015 programs (CEMMSS, CIF21, SaTC, and SEES), many of which are entering their final years of implementation, will be discontinued.

Goal 5, Research Infrastructure Investments
Lead Organization: Large Facilities Office, Office of Budget, Finance, and Award Management.

Strategic Alignment:

- Strategic Goal 1: Transform the Frontiers of Science and Engineering, Objective 3: Provide world-class research infrastructure to enable major scientific advances.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015	Ensure program integrity and responsible stewardship of major research facilities and infrastructure.	Construction Project Monitoring: For all MREFC facilities under construction that are over ten percent complete, keep negative cost and schedule variance at or below ten percent.	Not achieved.
Actual Results for Preceding Fiscal Years			



Discussion

The Major Research Equipment and Facilities Construction (MREFC) account supports the acquisition, construction, and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Performance of construction projects funded by the MREFC account is monitored using the Earned Value Management (EVM) system. EVM is an integrated management control system for assessing, understanding, and quantifying what a contractor or field activity is achieving with program dollars. Monitoring cost and schedule is a standard measure of performance for construction projects. Projects that are under ten percent complete are not considered eligible for this goal because EVM data is less meaningful statistically in the very early stages of a project.

Five of the six projects that were over ten percent complete by the end of FY 2015 were on track: 1) the Advanced Laser Interferometer Gravitational-wave Observatory (AdvLIGO) project is complete except for procurement and implementation of the Data Computing System (DCS); 2) the Daniel K. Inouye Solar Telescope (DKIST) made significant progress; 3) the Ocean Observatories Initiative (OOI) was successfully completed as planned on October 31, 2015; 4) the Alaska Region Research Vessel (ARRV), *Sikuliaq*, is nearing 98 percent complete following final negotiations with the shipyard. EVM reporting has been discontinued with spending now monitored through the awardee's general ledger in preparation for close-out; and 5) the Large Synoptic Survey Telescope (LSST) continues to make good technical progress and improvements in cost and schedule performance. For more information about all projects currently funded from the MREFC account, see the Major Research Equipment and Facilities Construction chapter of this submission.

Explanation of Unmet Goal
The National Ecological Observatory Network (NEON) experienced schedule performance issues in FY 2015 and is being re-scoped. NSF continues to be highly involved with oversight now that the project has crossed the -10 percent performance threshold.

Goal 6, Evaluate NSF Investments
Lead Organization: Office of Integrative Activities.

Strategic Alignment:
- Strategic Goal 1: Transform the Frontiers of Science and Engineering, All Objectives.
- Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education, All Objectives
- Strategic Goal 3: Excel as a Federal Science Agency, All Objectives

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015 (new goal)	Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.	1. By September 2015, the Evaluation and Assessment Capability will have developed evaluation quality principles and disseminated them to all directorates. 2. These quality principles will be followed by all new evaluation projects across the agency. 3. NSF will have incorporated logic models/theory of change in the language that describes the rationale for all new programs.	1. Not achieved. 2. Not achieved. 3. Not achieved.

Discussion
The Evaluation and Assessment Capability (EAC), housed in the Office of Integrative Activities, provides NSF with the independent capacity to operate from a basis of evidence in program and policy decisions. The EAC has three multi-year goals: 1) encourage a culture of evidence-based planning and policy-making; 2) encourage increased rigor, independence, and consistency in all evaluations and assessments; and 3) develop and implement a coordinated evaluation framework. This performance goal, new in FY 2015, was intended to contribute towards these longer-term goals.

In FY 2015, NSF funded a series of workshops with international experts in the evaluation of science programs which was open to all NSF staff. The series accomplished the goal of disseminating the need for rigor in evaluation projects to staff NSF-wide. The report from the workshop series was used to inform the appropriate methodologies and methods for programs of different sizes and type.

Explanation of Unmet Goal
For target 1, the principles were developed in FY 2015, but not finalized. Achievement of targets 2 and 3 were contingent on the fulfillment of target 1.

<u>Goal 7, Diversity and Inclusion</u>
Lead Organization: Office of Diversity and Inclusion, Office of the Director.

Strategic Alignment:

- Strategic Goal 3: Excel as a Federal Science Agency, Objective 1: Build an increasingly diverse, engaged, and high-performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015	Foster an environment of diversity and inclusion while ensuring compliance with the agency's Equal Employment Opportunity (EEO) and civil rights programs.	1. Continue to perform as a model EEO agency. 2. Perform two compliance desk reviews under the applicable anti-discrimination laws.	1. Not achieved (five of six essential elements attained: A, B, C, D, & F). 2. Achieved.
Actual Results for Preceding Fiscal Years			
2014	Foster an environment of diversity and inclusion while ensuring compliance with the agency's civil rights programs.	1. Attain six of six essential elements of a model EEO agency. 2. Assist in implementation of one ODI action within NSF's D&I Strategic Plan. 3. Perform two compliance desk reviews under the applicable antidiscrimination laws.	1. Not achieved (four of six essential elements attained: A, C, D, & E). 2. Achieved. 3. Not achieved.
2013	Perform activities necessary to attain essential elements of a model EEO agency, as defined by the Equal Employment Opportunity Commission (EEOC).	Attain five of six essential elements.	Achieved (five elements attained: A-E).
2012	Perform activities necessary to attain essential elements of a model EEO agency, as defined by the EEOC.	1. Attain four of six essential elements. 2. Submit Diversity and Inclusion Strategic Plan to OPM by March 30, 2012.	1. Achieved (four elements attained: C, D, E, & F). 2. Achieved.
2011	Attain essential elements of a model EEO agency, as defined by the EEOC.	Three elements.	Achieved (three elements attained A, B, & C).

Discussion
For NSF to attain model EEO agency status, it must meet and maintain each of the six criteria established by the Equal Employment Opportunity Commission (EEOC). The EEOC refers to these criteria as the "Essential Elements" of a Model Agency (see table below). In FY 2015, NSF complied with five of the six essential elements towards attaining a model EEO Agency Program: elements A, B, C, D, and F.

In 2014, NSF expanded this goal in two ways, which continued in FY 2015. First, NSF set a target to attain all of the elements of a model EEO agency—a status no agency has currently attained. Second, NSF added a target to conduct two desk reviews under Title IX of the Education Amendments of 1972 (hereinafter Title IX), which prohibits discrimination based on gender in any educational program or activity receiving federal financial assistance. In FY 2015, NSF was successful in performing two onsite Title IX compliance reviews: 1) April 2015 at the University of Tennessee's College of Engineering's Graduate Department of Electrical Engineering and Computer Science and 2) September 2015 at the University of Utah's College of Engineering's Graduate Department of Mechanical Engineering.

Explanation of Unmet Goal
For target 1, NSF attained 5 of 6 essential elements of a model EEO Agency. Delays in processing of disputes inhibited achievement of element E, Efficiency.

EEOC Essential Element Definitions and NSF Activities

Essential Element	NSF Activities
A: Demonstrated commitment from agency leadership requires the agency head to issue a written policy statement ensuring a workplace free of discriminatory harassment and a commitment to equal employment opportunity.	NSF achieved and complied with essential element A including ensuring that EEO policy statements were current, communicated to all employees, and vigorously enforced by agency management.
B: Integration of EEO into the agency's strategic mission requires that the agency's EEO programs be organized and structured to maintain a workplace that is free from discrimination in any of the agency's policies, procedures, or practices and supports the agency's strategic mission.	NSF has continued to fully achieve and comply with all of essential element B when it ensured the reporting structure for the EEO program provides the principal EEO official with appropriate authority and resources to effectively carry out a successful EEO program; the EEO office has a regular and effective means of informing the agency head and senior management officials of the status of EEO programs; the EEO office is involved in, and is consulted on, management/personnel action; and NSF has committed sufficient human resources and budget allocations to its EEO programs to ensure successful operation.
C: Management and program accountability requires the agency head to hold all managers, supervisors, and EEO officials responsible for the effective implementation of the agency's EEO Program and Plan.	NSF achieved compliance with essential element C. NSF has continued to fully achieve and comply with the EEO program officials advising and providing appropriate assistance to managers/supervisors about the status of EEO programs within each manager's or supervisor's area of responsibility. NSF achieved the measure of whether the human resources director and the EEO director meet regularly to assess whether personnel programs, policies, and procedures are in conformity with instructions contained in EEOC management directives regarding the implementation of schedules to review Merit Promotion Program Policy, Employee Recognition Awards Program, and Employee Development/Training Programs.

Essential Element	NSF Activities
D: Proactive prevention requires that the agency head makes early efforts to prevent discriminatory actions and eliminate barriers to equal employment opportunity in the workplace.	NSF has continued to fully achieve and comply with all of essential element D when it conducts analyses to identify and remove unnecessary barriers to employment throughout the year; and encourages the use of alternative dispute resolution with involvement of senior management.
E: Efficiency requires that there are effective systems in place for evaluation of the impact and effectiveness of the agency's EEO programs as well as an efficient and fair dispute resolution process.	NSF met all but two measures under essential element E when it provided sufficient staffing, funding, and authority to achieve the elimination of identified barriers; provided an effective complaint tracking and monitoring system to increase the effectiveness of the agency's EEO programs; provided sufficient staffing, funding, and authority for processing EEO complaints of employment discrimination; provided an effective and fair dispute resolution process and effective systems for evaluating the impact and effectiveness of the agency's EEO complaint processing program; and implemented effective systems for maintaining and evaluating the impact and effectiveness of its EEO programs. Areas of improvement include ensuring counseling is complete in a timely manner and investigations are conducted within the applicable timeframes.
F: Responsiveness and legal compliance requires that federal agencies are in full compliance with EEO statutes and EEOC regulations, policy guidance, and other written instructions.	NSF has continued to fully achieve and comply with all of essential element F when the agency's system of management controls ensures that the agency completes all ordered corrective actions in a timely manner and submits its compliance report to EEOC within 30 days of such completion; and agency personnel are accountable for the timely completion.

Goal 8, Evidence-Based Management
Lead Organization: Office of Information and Resource Management

Strategic Alignment:
- G3: Excel as a Federal Science Agency, All Objectives

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015	Use evidence-based reviews to guide management investments.	HRStat measures: 1. Establish indicators to assess the impact and progress of three workforce initiatives designed to advance progress toward or address barriers to the accomplishment of mission related goals and objectives. 2. During FY 2015, focus at least two evidence-based reviews on the three identified workforce initiatives. PortfolioStat measures: 3. NSF's information technology governance boards will evaluate and prioritize proposed investments for FY 2017. 4. NSF's information technology governance boards will use cost and schedule data on existing investments to inform investment decisions for FY 2017. Percentage of IT projects within ten percent of budgeted costs and percentage of IT projects within ten percent of budgeted schedule will be tracked.	1. Achieved. 2. Achieved. 3. Achieved. 4. Achieved.
Actual Results for Preceding Fiscal Years			
2014 (new goal)	Use evidence-based reviews to guide management investments.	HRStat measures: 1. Develop a human capital management dashboard to report progress toward human capital (HC) goals and to monitor HC metrics, for use as an internal resource for informing investment decisions. 2. Establish a review process which culminates in quarterly reviews of HC metrics by senior management and which incorporates, to the extent possible, OPM's human capital accountability system requirements. PortfolioStat measures: 3. NSF's IT governance boards will evaluate and prioritize proposed investments for FY 2016. 4. NSF will move toward a standardized computing environment, reducing purchase costs by $300,000 below FY 2012 levels by FY 2014. 5. Migration to cloud email provider will reduce costs by approximately $240,000 below FY 2012 levels by FY 2014.	1. Achieved. 2. Achieved. 3. Achieved. 4. Achieved. 5. Achieved.

Discussion

HRStat and PortfolioStat are processes in which agency leaders conduct regular data-driven reviews of human resources or IT portfolio information.

- HR Stat: targets 1 and 2. In FY 2014, NSF developed a first-generation human capital management dashboard for senior management use. The dashboard includes Federal Employee Viewpoint Survey measures and internal HR data and provides information on four human capital focus areas. These areas are subject to change as topics are identified or de-emphasized by leadership.

  In FY 2015, NSF met target 1 by selecting three areas of focus for workforce initiatives: Employee Engagement, Hiring and Losses, and Workload. Employee Engagement indicators include the government-wide Employee Engagement Index (EEI) and NSF's Joint Engagement Index (JEI). Hiring and Losses indicators include time-to-hire data, loss rates, IPA costs and turnover, FTE utilization, and retirement eligibility. Workload indicators include NSF's Workload Index and the NSF weighted workload model. HRStat meetings in Q1, Q2, and Q4 satisfied target 2 in FY 2015.

- Portfolio Stat: targets 3 and 4. These targets monitor NSF's IT investment evaluation process. NSF's IT investments support the Foundation's business needs through a formal and disciplined IT investment review and decision-making process. Specifically, NSF's process for approving centrally-funded IT investments requires advocates for new IT investments to complete detailed justification and business case documentation. This ensures that advocates for new IT investments have fully considered the business need, benefits, impacts, and strategic alignment of each potential investment. This also helps the CIO and governance boards verify that IT, rather than policy changes or business process reengineering, is the appropriate solution to a business need. The process provides NSF's CIO and governance boards the information needed to review, approve, and prioritize investment proposals using a comprehensive evaluation methodology. This process was successfully used to prepare the FY 2017 IT budget request and prioritize the IT investment portfolio.

  Target 4 speaks specifically to the requirement to monitor in-process investments cost and schedule to inform funding discussions for each year (FY 2017 for this report). This ensures that governance boards are aware of the progress and accomplishments for those investments that they recommended for funding.

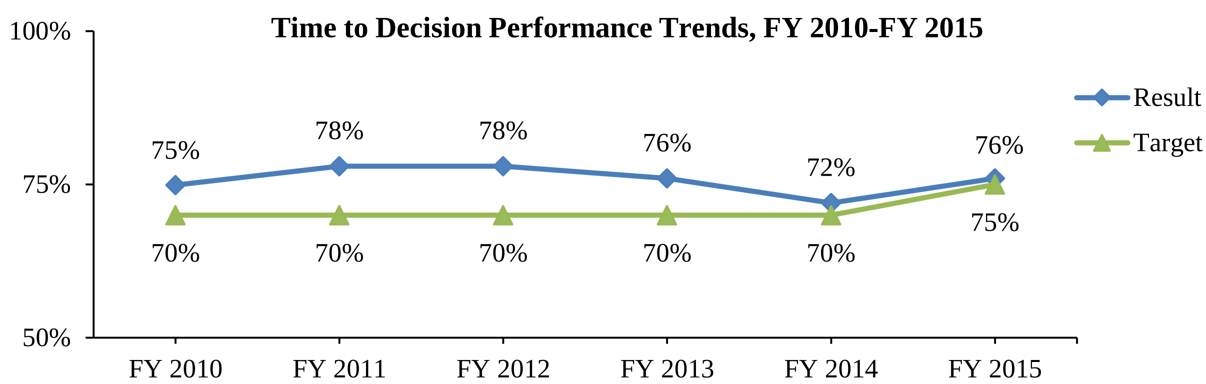
<u>Goal 9, Customer Service: Time to Decision</u>
Lead Organization: Office of Integrative Activities.

Strategic Alignment:

- Strategic Goal 3: Excel as a Federal Science Agency, Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

FY	Goal Statement	Target Measure	Result
2015	Inform applicants whether their proposals have been declined or recommended for funding within 182 days, or six months, of deadline, target, or receipt date, whichever is later.	75 percent.	Achieved (result = 76 percent).

Actual Results for Preceding Fiscal Years



Discussion
Time to decision or "dwell time" is the amount of time that passes between receipt of a proposal and notification to the principal investigator about the funding decision. One of the most significant issues raised in customer satisfaction surveys is the time it takes NSF to process proposals. Too long a time period inhibits the progress of research as it delays the funding process, but too short a time period may inhibit the merit review process. The six-month target seeks to strike a balance between the need of the investigator for timely action and the need of NSF for a credible and efficient merit review system.

In FY 2015, this target was raised from 70 to 75 percent to be more in line with the historical trend of achievement at or above this level (NSF exceeded the 70 percent target in FY 2014 by a historically low margin, likely due to Foundation-wide delays in proposal processing after the lapse in funding authority in October 2013). The FY 2015 result of 76 percent was in line with historical achievement.

Goal 10, Proposal Review Efficiency
Lead Organization: Office of Integrative Activities, Office of the Director.

Strategic Alignment:
- Goal 3: Excel as a Federal Science Agency, Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

FY	Goal Statement	Target Measure, Milestone, or Deliverable	Result
2015	Identify new approaches to keep NSF's world-renowned merit review process innovative, effective, and efficient.	1. At least 33 percent of merit review panels will be wholly virtual panels. 2. At least five divisions explore use of asynchronous panels. 3. Pilot at least two additional innovative merit review mechanisms. 4. Assess the results from two merit review pilot activities conducted prior to FY 2015. 5. Complete assessments of synchronous virtual panel pilot.	1. Not achieved (result = 25.2 percent). 2. Not achieved (result = two divisions). 3. Achieved. 4. Achieved. 5. Achieved.
Actual Results for Preceding Fiscal Years			
2014	Improve the ability to use virtual merit review panels by incorporating technological innovations into review process.	15 percent of merit review panels will be wholly virtual panels.	Achieved (result = 29.6 percent).
2013	Expand the use of virtual merit review panels.	As a pilot activity, five percent of merit review panels will be virtual panels.	Achieved (result = 26.3 percent).
2012	Expand the use of virtual merit review panels.	By September 30, 2012, develop guidelines and training modules for NSF staff on the use of virtual merit review panels.	Achieved

Discussion
NSF makes extensive use of panels of reviewers to evaluate proposals. The predominant practice is for the panelists to travel to a single location, usually NSF, and meet face-to-face for one to five days. Approximately 1,900 review panels are held each year. Face-to-face panels impose a significant time burden on the reviewers, making some potential reviewers reluctant to participate. For example, panelists with young children may not be able to obtain two continuous days of childcare, or panelists in remote locations or foreign countries may find the amount of travel required prohibitive. It also causes NSF to incur significant travel costs.

Review panels provide ample opportunity to test new methods and practices. One such practice, the use of virtual meeting technology to replace in-person panels, has been the subject of pilot testing and performance goals since FY 2010. As used in reference to this goal, the term "virtual panel" refers to a panel meeting in which the reviewers do not travel to a common location but instead participate via teleconference, videoconference, or an online meeting technology. In FY 2015, this goal expanded to also monitor other aspects of the merit review pilot process.

FY	Total Panels	Wholly Virtual Panels	% Wholly Virtual Panels
2011	1763	55	3.1%
2012	1801	149	8.3%
2013	2073	545	26.3%
2014	1986	588	29.6%
2015	2131	537	25.2%

In FY 2012, 1801 panels were held, of which 149 (8.3 percent) were wholly virtual In FY 2013, 2073 panels were held, of which 545 were wholly virtual (26.3 percent), exceeding the FY 2013 target of five percent wholly virtual panels. In FY 2014, a total of 1986 panels were held of which 588 were wholly virtual (29.6 percent), exceeding the FY 2014 goal of 15 percent of wholly virtual panels. This significant increase in virtual participation over prior years can be attributed to several factors: a response to reductions in travel budgets; development of virtual panel training materials; and management's encouragement to utilize virtual panels as a viable reviewer participation mechanism.

In FY 2015, targets 1 and 2 were not met. For target 1, the result is 25.2 percent, below the 33 percent target. For target 2, only two divisions participated in the pilot. The remaining targets were achieved. For target 3, three pilots were successfully deployed in FY 2015: asynchronous panels, e-polling, and virtual sidebar discussions. Targets 4 and 5 were achieved; assessments of the pre-FY 2015 merit review pilots, were produced, as well as an assessment of the virtual panel pilot. These affirm NSF's commitment to understanding how and why merit review pilot innovations are or are not successful. The assessments are likely to be used in future scaling efforts designed to expand use of the innovations.

Explanation of Unmet Goal

Targets 1 and 2 were not met. Because of the range of approaches to merit review across organizational units, NSF management adopted a voluntary approach to participation to merit review pilots in FY 2015. This approach did not secure the necessary level of participation to meet these two targets.

FY 2017 ANNUAL PERFORMANCE PLAN

NSF's FY 2017 Performance Plan reflects NSF's priorities as identified through its planning and budget process. The table below provides a summary of NSF's performance goals for FY 2017 and two new Agency Priority Goals (APGs) for FY 2016 and FY 2017. The remaining pages of this section provide a detailed description of each goal along with the proposed target measures, milestones, or deliverables.

ID	Goal Short Title	Lead Organization	Goal Statement
1	Agency Priority Goal: Improve Graduate Student Preparedness	GEO and ENG	Improve STEM graduate student preparedness for entering the workforce. By September 30, 2017, NSF will fund at least three summer institutes and 75 supplements to existing awards to provide STEM doctoral students with opportunities to expand their knowledge and skills to prepare themselves for a range of careers.
2	Agency Priority Goal: Invest Strategically in Public Participation in STEM Research (PPSR)	EHR and CISE	Build the capacity of the Nation to solve research challenges and improve learning by investing strategically in crowdsourcing and other forms of public participation in science, technology, engineering, and mathematics research (PPSR). By September 30, 2017 NSF will implement mechanisms to expand and deepen the engagement of the public in STEM research.
3	Ensure that Key Program Investments are on Track	BFA	Ensure that key FY 2017 NSF-wide program investments are implemented and on track.
4	Ensure that Infrastructure Investments are on Track	BFA	Ensure program integrity and responsible stewardship of major research facilities and infrastructure.
5	Use Evidence to Guide Management Decisions	OIRM	Use evidence-based reviews to guide management investments.
6	Make Timely Award Decisions	OIA/OD and BFA	Inform applicants whether their proposals have been declined or recommended for funding in a timely manner.
7	Foster a Culture of Inclusion	ODI/OD	Foster a culture of inclusion through change management efforts resulting in change leadership and accountability.
8	Evaluate NSF Investments	OIA/OD	Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.

9	Increase the Percentage of panelists participating in merit review virtually	OIA/OD	Increase the percentage of proposal review panelists that participate virtually while maintaining the quality of the merit review process.

Goal 1: Agency Priority Goal: Improve Graduate Student Preparedness

Goal Statement	Improve STEM graduate student preparedness for entering the workforce. By September 30, 2017, NSF will fund at least three summer institutes and 75 supplements to existing awards to provide STEM doctoral students with opportunities to expand their knowledge and skills to prepare for a range of careers
Indicator and Target Measure, Milestone, or Deliverable	Number of summer institute sessions funded ≥3 Number of supplements funded ≥75 Number of students supported by supplements
Description	A strong global economy is reliant on the ability to capitalize on technical innovations that result from a skilled and agile STEM workforce. As a result, the Nation's scientific workforce must evolve and mature to include more doctoral level researchers in positions outside of academia. These positions require comprehensive preparation in science at the graduate level, as well as proficiency in other critical skills. Surveys of graduate students analyzed in recent reports have demonstrated that graduate student training has not kept pace with STEM workforce needs beyond traditional roles in academia. In recent years there has been a shift in the job market for science and engineering doctorate holders that has resulted in more varied career choices. Scientists and engineers with doctorates are now more evenly split between the business sector (45 percent) and the education sector (46 percent) (Source: Survey of Doctorate Recipients, National Science Foundation, National Center for Science and Engineering Statistics 2013). Within the education sector, over 90 percent of doctorates are employed at four-year institutions. However, Ph.D. training remains largely focused on preparation for the research component of academic careers with an emphasis on skills needed at research institutions. There is considerable value to traditional academic training, which can provide doctoral graduates with experience in critical thinking as well as oral and written communication that are beneficial in a wide range of careers. However, opportunities to acquire broad knowledge, experience, or skills that are useful in other sectors (business, government, non-profits, etc.) are often lacking. The purpose of this APG is to provide opportunities for science and engineering doctoral students so they can acquire the knowledge, experience, and skills needed for highly productive careers, inside and outside of academe. Although investments in the Graduate Research Internship Program (GRIP) and Graduate Research Opportunities Worldwide (GROW) provide support across disciplines that help address this issue, a larger, agency-wide effort directed at the specific goal of determining effective approaches to increased graduate student preparedness is needed. The activities in this APG will be undertaken in coordination with NSF's forthcoming strategic framework for investment in graduate education. In addition, these approaches will be reported at the National Science and Technology Council (NSTC) Committee on STEM Education's Interagency Working Group on Graduate Education (co-chaired by NSF and the National Institutes of Health).

	The NSTC Committee on STEM notes that "tomorrow's STEM workforce will need to include effective change makers and entrepreneurs in business, public service, civil society, and academia. Some universities are encouraging students to set and meet more ambitious goals for their research, education, and service; giving students greater autonomy earlier in their career; connecting students to real-world problems at a regional, national, and global level; and involving students in the design of university curricula, research initiatives, and collaborations with external partners." This APG will explore ways to partner with universities to identify and spread promising practices for achieving this vision. **Strategies** To achieve this APG, NSF will pilot two approaches that invite the community to propose a range of solutions to improve doctoral student preparedness for entering the workforce. 1. Support <u>summer institutes</u> that propose convincing, theory, or evidence-based strategies for how to provide students with broad experiences in professional development areas that have been identified in numerous reports as being essential for workforce preparedness. Summer institutes may be awarded for interdisciplinary activities as well as those that are discipline-specific; partnerships with industry, government, and other sectors will be encouraged. 2. Provide support for <u>supplements</u> to existing research awards to enhance graduate education opportunities at two levels. *Enhanced experience* awards will enable single/collaborative awardees to request appropriate levels of additional support for existing graduate students to acquire professional development experience that will broaden avenues for entering the workforce. These supplements could provide graduate students with the opportunity to augment their assistantships/fellowships with additional "mentoring" activities and short-term training opportunities. *Enhanced activities* awards will be available to larger institution-level, "center-like" activities to support cohorts of graduate students with the goal of developing new "best practice activities" for enhancing graduate student preparedness for entering the workforce. At the end of the award, after the term of this APG, all principal investigators (PI) will document implementation of their approach in their final report to advise on potential scaling to other institutions in the future. For both the summer institutes and supplemental awards, a common set of metrics will be developed and provided to awardees to assist in verifying the impacts and benefits of these approaches. By the end of FY 2017, NSF will support at least three two-year summer institutes where PIs will be invited to propose evidence-based and evidence-generating strategies and approaches to improve the preparation of graduate students for a wider variety of careers. By the second quarter of FY 2016, NSF will release a Dear Colleague Letter to encourage requests for supplements to existing NSF awards that will support innovative and useful approaches for doctoral student preparedness. At least seventy-five supplements will be awarded in total in FY 2016 and FY 2017.

	Analysis of awards made as part of this priority goal will inform steps to be taken beyond FY 2017 regarding whether to scale up or specifically target ideas that emerge from priority goal activities. In addition, all students who benefit from participation in the institutes or through the supplements will have the opportunity to complete follow-up surveys so that their career paths and readiness for those career paths can be monitored. Analysis of these data will be completed after the end of this APG. **Timeline** FY 2016 Quarter 2: Release Dear Colleague Letter to solicit applications for supplements. FY 2016 Quarter 3: A common set of metrics will be developed and provided to awardees of both summer institutes and supplemental awards. FY 2016 Quarter 3: Request proposals for summer institutes. FY 2017 Quarter 1: Award at least three summer institutes. FY 2017 Quarter 3: Initiate portfolio analysis of awards made. FY 2017 Quarter 4: At least seventy-five supplements awarded.
Trend Information	This is a new goal in FY 2016. The topic was identified as a priority from the 2015 Strategic Review process.
Strategic Alignment	Strategic Goal G1: Transform the frontiers of science and engineering, Objective 2: Integrate education and research to produce a diverse STEM workforce with cutting-edge capabilities.
Lead Organization/s	Directorate for Geosciences Directorate for Engineering

Goal 2: Agency Priority Goal: Invest Strategically in Public Participation in STEM Research (PPSR)

Goal Statement	Build the capacity of the Nation to solve research challenges and improve learning by investing strategically in crowdsourcing and other forms of public participation in science, technology, engineering, and mathematics research (PPSR). By September 30, 2017, NSF will implement mechanisms to expand and deepen the engagement of the public in research.
Indicator and Target Measure, Milestone, or Deliverable	Success will be indicated by achieving milestones and by meeting target metrics. These milestones and metrics are: 1. NSF will fund at least two convenings that include current or possible stakeholders external to the federal government to identify trends, opportunities, and gaps in PPSR. These convenings will inform how NSF targets funding opportunities towards scientific needs and public audiences. Milestones: FY 2016 Q3 & FY 2017 Q2. 2. NSF will confer with other federal agencies at least three different times in order to inform and coordinate efforts related to PPSR. Milestones: FY 2016 Q2; FY 2016 Q3; FY 2017 Q3. 3. NSF will issue one specific call for Research Coordination Networks (RCNs). Milestone: FY 2016 Q3. Indicator: At least one RCN is funded in FY 2017 Q2. 4. NSF will solicit EArly-concept Grants for Exploratory Research (EAGERs) that include PPSR. Indicator: NSF funds at least five EAGERs that include PPSR in both FY 2016 Q4 and FY 2017 Q4. 5. NSF will solicit supplements that include PPSR. Indicator: NSF funds at least five supplements that include PPSR in both FY 2016 Q4 and FY 2017 Q4. 6. NSF will issue at least two communications highlighting PPSR and related funding opportunities. Indicators: FY 2016 Q3; FY 2017 Q2.
Description	Scientists, mathematicians, and engineers have involved the public in their research efforts to solve challenging problems for centuries in a variety of fields. For example, daily precipitation data collected by volunteers throughout the U.S. have been used to develop more accurate, fine-grained models that improve weather forecasting, agriculture, and disaster risk analyses. Water quality and wildlife monitoring projects allow communities to understand their local environments in systematic ways and allow them to compare their findings with those from other areas. These types of activities have been referred to in a variety of ways. For this APG, PPSR is used as an overarching term that includes citizen science, crowdsourcing research, and similar activities. PPSR has grown significantly in the past decade, in part due to new technological tools that facilitate interactions between scientists and participants. There are a number of economic, societal, and technological trends that are increasing the variety and value of what public participation in research can accomplish. These trends include: the democratization of the tools needed to design and make a variety of items; the Maker Movement; the emergence of online communities with shared interests in projects such as exploration of diverse fields of science, technology,

	engineering, and mathematics (STEM) by members of the public; and crowdfunding platforms that allow teams to raise funding for their projects. New technological tools also have facilitated crowdsourcing research, a process in which open calls are made for voluntary contributions to STEM problem-solving. These calls are typically either to a non-specified group of individuals ("the crowd") or to individuals with specific expertise, thus leveraging the skills and knowledge of many. Without public participants and their contributions, some STEM research that addresses challenging problems would not be practical or even possible, e.g., projects mandating data collection from many geographical locations or over long periods of time or projects that require expertise for analysis of data as well as large sets of visual or numeric data. PPSR approaches hold promise to continue to address new research questions and contribute to ongoing STEM research. Moreover, citizen science and crowdsourcing research provide opportunities for the broadest possible participation in learning how STEM research is done and in engaging in it directly. Participants include individuals from urban, suburban and rural communities; diverse economic, geographic, racial, ethnic, gender, and linguistic groups; and individuals with a range of abilities and disabilities. The motivation for PPSR may be derived from community concerns or may be researcher-led. The level of public involvement varies from being contributory (e.g., collecting and recording data) to collaborative (e.g., analyzing samples and discussing results) to co-created (in which the public might be involved in all phases of the scientific process from defining the question for investigation, to experimenting, analyzing, and reporting). Thus, people with various interests and abilities are often able to participate and contribute productively. With the opportunity to reach more people and therefore collect and analyze data sets more extensively than possible through the efforts of scientists alone, PPSR may go beyond simply enhancing our ability to do traditional STEM research better. Citizen science and crowdsourcing science enable us to pursue entirely *new avenues of research and development* that can only be achieved through public-scientist collaborations. The different perspectives and habits of mind that public participants can bring to bear on the interpretation of data may also open new avenues of research and development. Over the past decade, NSF has funded hundreds of STEM research projects that rely on PPSR across a diverse array of fields. The scope of PPSR is broad and encompasses geosciences and biological sciences, technology and engineering, social and behavioral sciences, education, computer and information sciences, and physical sciences. These projects collectively have created a strong foundation for future PPSR activities and have identified areas for potential improvement and expansion. The next phase of NSF investments will expand beyond project-by-project approaches to explore underlying issues and areas for innovation. In particular, this next phase could help identify: new research challenges that might be addressed using PPSR; new PPSR-enabling technology; social aspects of working with the public; effective PPSR program design; learning experience facilitated by PPSR; ways in which PPSR can broaden participation in STEM; and

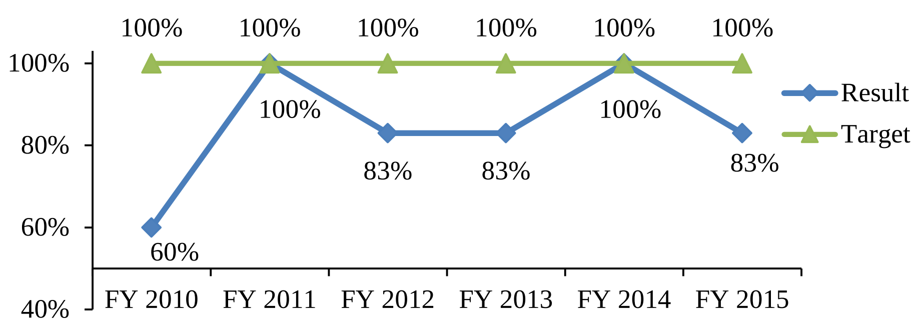
	a myriad of data-related issues, including data quality and collection, data management, visualization, and data ownership models. This phase of investments should also prompt the broader community to tackle long-standing but unresolved STEM challenges and to open doors to new STEM research areas. To achieve this APG NSF will use three specific mechanisms to fund proposals that explicitly include PPSR approaches: Research Coordination Networks (RCNs), EAGERs, and supplements to existing awards. RCNs support communication and coordination across disciplinary, organizational, institutional, and geographic boundaries, thus facilitating ongoing activities above the project level. EAGERs are designed as "high risk-high payoff" awards. These types of awards will likely push our collective understandings of how PPSR is leveraged to support scientific discovery and the public's engagement with research. Supplements to existing awards provide opportunities to (1) include PPSR approaches in projects that are appropriate for PPSR but haven't already incorporated PPSR approaches and (2) for other projects to deepen their use of PPSR approaches. This APG also takes advantage of the Executive Branch's momentum in this area. For example, the White House honored Citizen Science Champions of Change and included citizen science projects and opportunities in its recent science fair. Office of Science and Technology Policy (OSTP) rolled out a new toolkit for federal-sponsored PPSR projects on September 30, 2015 and issued a memo with actions for federal agencies with respect to PPSR. Among the public communities that NSF serves, this APG is relevant and timely. It addresses the need for investments in PPSR as articulated in recent journals, such as *Science*; at conferences, such as the citizen science pre-conference workshop at AAAS in 2015; and by practitioner organizations, such as the Citizen Science Association. **Key barriers and challenges to its achievement** 1. Coordinate cross-program and cross-directorate investments that enhance both an understanding of and ability to implement PPSR approaches. 2. Manage expectations among colleagues across the federal government and public sphere as PPSR is further developed to support their daily work. **External factors** OSTP and the Federal Community of Practice for Citizen Science and Crowdsourcing (FCPCSC) have directly contributed to development of this APG. In addition, activities by federal agencies and offices related to open innovation, citizen science, and crowdsourcing research will inform the state of the field with respect to challenges and opportunities in PPSR.
Trend Information	This is a new goal in FY 2016. The topic was identified as a priority from the 2015 Strategic Review process.
Strategic Alignment	Strategic Goal G1: Transform the frontiers of science and engineering, Objective 1: Invest in fundamental research to ensure significant continuing advances across science, engineering, and education.

	Objective 2: Integrate education and research to produce a diverse STEM workforce with cutting-edge capabilities. Strategic Goal G2: Stimulate Innovation and Address Societal Needs through Research and Education, Objective 2: Build the capacity of the Nation to address societal challenges using a suite of formal, informal and broadly available STEM educational mechanisms.
Lead Organization/s	Directorate for Education and Human Resources Directorate for Computer and Information Science and Engineering

Goal 3: Ensure that Key Program Investments are on Track

Goal Statement	Ensure that key FY 2017 NSF-wide program investments are implemented and on track.
Indicator and Target Measure, Milestone, or Deliverable	1. Monitor the progress of the following NSF-wide investments using a common set of milestones and indicators: NSF INCLUDES, INFEWS, Risk and Resilience, and UtB. 2. Review the results with senior leaders quarterly in data-driven performance reviews.
Description	Key investments will be strategically monitored using a set of common metrics. These may include: • Contextual indicators, such as the investment's funding level. • Input indicators, such as date of release of solicitation, number of proposals received, numbers of reviews conducted. • Output indicators, such as number of awards, average and total amounts awarded, and funding rate. • Medium-term output and outcome indicators that gauge whether funded projects are on track. • Activity-specific outcome indicators, e.g., those relating to programmatic long term goals. Progress will be assessed quarterly and discussed at quarterly review meetings with leadership.
Trend Information	This was a new goal in FY 2014. In FY 2014, NSF monitored the implementation and progress of CIF21, CEMMSS, SaTC, and SEES. In FY 2015, UtB was added. The list of monitored programs is subject to change each year based on strategic considerations. For more information on those goals, refer to NSF's FY 2014 and FY 2015 Annual Performance Reports.
Strategic Alignment	Strategic Goal G1: Transform the Frontiers of Science and Engineering, all Objectives (O1-O3). Strategic Goal G2: Stimulate Innovation and Address Societal Needs through Research and Education, all Objectives (O1-O2).
Lead Organization/s	Office of Budget, Finance, and Award Management

Goal 4: Ensure that Infrastructure Investments are on Track

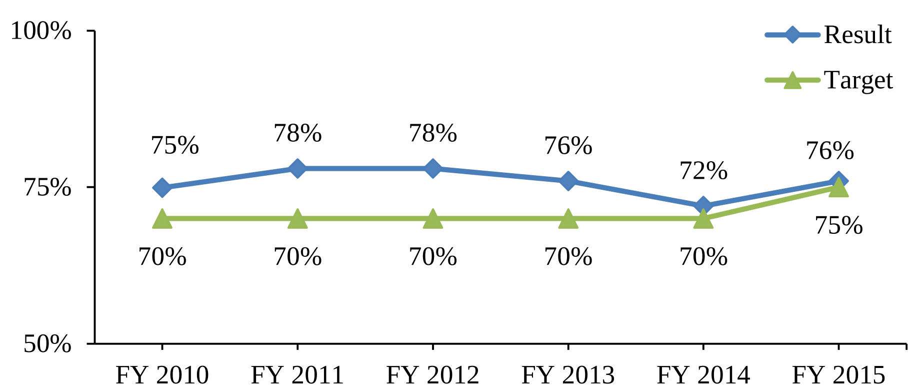
Goal Statement	Ensure program integrity and responsible stewardship of major research facilities and infrastructure.
Indicator and Target Measure, Milestone, or Deliverable	Construction Project Monitoring: For all Major Research Equipment and Facilities Construction (MREFC) projects under construction that are over ten percent complete, keep negative cost and schedule variance at or below ten percent.
Description	NSF monitors the performance of projects funded by the MREFC account by monitoring cost and schedule, a standard measure of performance for construction projects. Projects that are under ten percent complete are not considered eligible for this goal because Earned Value Management (EVM) data are statistically less meaningful in early stages.
Trend Information	**Construction Project Monitoring Performance Trends, FY 2010-FY 2015**  *Note.* For more information on end-of-year projections, which are below 100 percent, see NSF's FY 2015 Performance Report in this chapter.
Strategic Alignment	Strategic Goal G1: Transform the Frontiers of Science and Engineering, Objective O3: Provide world-class research infrastructure to enable major scientific advances.
Lead Organization/s	Large Facilities Office, Office of Budget, Finance, and Award Management

Goal 5: Use Evidence to Guide Management Decisions

Goal Statement	Use evidence-based reviews to guide management investments.
Indicator and Target Measure, Milestone, or Deliverable	PortfolioStat: 1. NSF's information technology governance boards will evaluate and prioritize proposed investments for FY 2016. 2. NSF's information technology governance boards will maintain a "green status" with investments on the Federal IT Dashboard for cost and schedule attributes (within 10 percent of target) associated with major IT investments. HRStat: 3. Monitor the progress of three workforce initiatives of strategic importance designed to meet the objectives of the Opportunities for Action in NSF's FY 2014 and FY 2015 Strategic Reviews for Strategic Goal 3, Objective 1. 4. Develop metrics to demonstrate whether NSF met its workforce goals for transition to the new NSF Headquarters.
Description	This goal captures NSF's commitment to two government-wide processes, PortfolioStat and HRStat, which aim to ensure that decisions regarding resource investments are made through formal processes involving cross-agency decision-makers. Data regarding business need, cost, and risk-analysis will be provided. This approach to decision making promotes transparency and accountability through data driven decision-making. As directed in OMB M-12-10, "Implementing PortfolioStat", NSF will employ this new tool to assess the current maturity of its IT portfolio management process, make decisions on eliminating duplication, augment current Chief Information Officer (CIO)-led capital planning and investment control processes, and move to shared solutions in order to maximize the return on IT investments across the portfolio. NSF will build upon its experience with HRStat, incorporate lessons learned from the development of its human capital dashboard, and continue to update and refine its evidence-based review process, as it establishes indicators and methods to measure human capital management initiatives aligned with the goals set out in the NSF Strategic Plan. The FY 2014 and FY 2015 Strategic Review processes and on-going human capital management planning activities have identified three broad areas for continuing, high-visibility workforce initiatives: hires and losses, employee engagement, and workload. In addition to initial development of key indicators for progress in these areas, NSF has targeted some aspects of the workforce for particular attention, such as the program officer workforce and the executive corps. FY 2017 will see the relocation of NSF's headquarters to Alexandria, VA and NSF will be able to assess outcomes relative to the FY 2014 Strategic Review recommendation of taking actions to ensure that 70 percent of the permanent workforce makes the move with the agency.

Trend Information	In FY 2014 through FY 2016, NSF developed workforce initiatives and processes and indicators for regular data-driven reviews of progress on the initiatives. Specifically, a human capital management dashboard was developed and three areas of focus for workforce initiatives were identified: 1) Engagement, 2) Hiring and Losses, and 3) Workload. In addition, NSF continues to closely monitor the IT investment evaluation process. See the Annual Performance Report for FY 2014 and Annual Performance Report for FY 2015 for more information.
Strategic Alignment	Strategic Goal G3: Excel as a Federal Science Agency, all Objectives (O1-O2).
Lead Organization/s	Office of the CIO and Office of the CHCO, Office of Information and Resource Management

Goal 6: Make Timely Award Decisions

Goal Statement	Inform applicants whether their proposals have been declined or recommended for funding in a timely manner.
Indicator and Target Measure, Milestone, or Deliverable	Inform 75 percent of applicants whether their proposals have been declined or recommended for funding within 182 days, or six months, of deadline, target, or receipt date, whichever is later.
Description	Time-to-decision or "dwell time" is the amount of time that passes between receipt of a proposal and notification to the principal investigator about the funding decision. One of the most significant issues raised in customer satisfaction surveys is the time it takes NSF to process proposals. Too long a time period inhibits the progress of research as it delays the funding process, but too short a time period may inhibit the merit review process. The optimal dwell time depends on a number of factors including the complexity of the proposed activity, the need for co-review by more than one panel, the need for site review, infrastructure requirements of the proposed activity, and the potential size of the award. Large, complex, proposals with a multi-stage review process require a lengthy dwell time to ensure that taxpayer dollars are invested wisely.
Trend Information	NSF has tracked six month dwell time as a performance goal for over a decade and has consistently met a target of 70 percent. In FY 2015, the six month target was increased to 75 percent, and NSF met the increased target. **Time to Decision Performance Trends, FY 2010-FY 2015** 
Strategic Alignment	Strategic Goal G3: Excel as a Federal Science Agency, Objective O2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.
Lead Organization/s	Office of Integrative Activities, Office of the Director Office of Budget, Finance, and Award Management

Goal 7: Foster a Culture of Inclusion

Goal Statement	Foster a culture of inclusion through change management efforts resulting in change leadership and accountability.	
Indicator and Target Measure, Milestone, or Deliverable	Revised FY 2016 Goal	FY 2017 Goal
	By September 30, 2016, ODI will conduct the new IQ process with two NSF organizational units. Improve the two NSF organizational units' New IQ Self-Survey Scores by five percent above established baseline.	By September 30, 2017, ODI will conduct the new IQ process with three additional organizational units. Improve the three NSF organizational units' New IQ Self-Survey Scores by seven percent above established baseline.
Description	Fostering inclusive work environments and realizing the full potential of the workforce's diversity requires agencies to employ effective management practices. The Office of Personnel Management (OPM), in partnership with the Department of Veterans Affairs, developed the New Inclusion Quotient (New IQ) in FY 2013 to drive inclusive intelligence in the federal workplace. Inclusive intelligence is the intentional, deliberate, and proactive acts that increase work group intelligence by ensuring people feel they belong and are uniquely valued. The New IQ consists of 20 questions identified through a rigorous factor analysis trial of the Federal Employee Viewpoint Survey (FEVS) questions with the highest correlation to inclusive environments. The questions are grouped into five habits of inclusion, F.O.C.S.E (Fair, Open, Cooperative, Supportive, Empowering). OPM's Office of Diversity and Inclusion (ODI) has recently developed a process to supplement use of the New IQ. The process uses a set of change management tools that equip agencies with instruments and practices necessary to support diversity and inclusion more fully. The 90-day process is designed to help leaders strengthen their workplace teams to their fullest potential by leveraging unique experiences, perspectives, and viewpoints of all members of the team. A self-survey will be conducted at the beginning of the ninety-day process to establish a baseline and then again at the end of the process. The expected outcome of the process is that the leaders will improve the employee engagement levels of their employees, resulting in an increase in the overall New IQ scores and corresponding FEVS scores over time. The New IQ Contagious Change Framework begins with training a small number of people in a set of behaviors, spread through the organization with the expectation that these behaviors will result in sustainable change. NSF has realized slippage in the FEVS inclusion-related results over several years and recognizes that having a workforce comprised of a mix of permanent and temporary rotator staff requires specific targeted efforts to ensure that behaviors are learned, practiced, and developed into habits of inclusiveness. In addition, NSF's workforce is challenged on another inclusion front with the administrative and scientific staffs' feelings about uniqueness and belongingness. NSF anticipates that implementing the New IQ process in several of NSF's	

	organizational units will initiate a set of behavior changes that can become contagious habits of inclusion throughout the Foundation. NSF ODI will implement the New IQ process in an organizational component in six steps: 1) Meet with the leadership team, provide an overview of the New IQ process, and set up their New IQ survey; 2) Meet with leadership team, review respective New IQ scores, identify implementation dates and identify potential change agents; 3) Conduct change agent training with 10 to 20 selected participants; 4) Conduct 4 hour New IQ workshop for the organization's participants; 5) Conduct regular checkups over 6 weeks with workshop participants; and 6) Conduct 90 minute action planning seminar to review participant action plan and make modifications to ensure success. Initially, ODI will work with leadership to identify organizational units to participate. The ideal participant would be a unit with both concerns about their level of inclusiveness and an openness to change.
Trend Information	NSF has had a performance goal relating to diversity and inclusion since FY 2011. Focusing specifically on inclusion represents a new direction for this goal in FY 2016, one that reflects the priorities of current leaders at NSF which aligns with the federal and private sectors. This is a revised performance goal in FY 2016 that replaces the goal published in the FY 2016 Budget.
Strategic Alignment	Strategic Goal G3: Excel as a Federal Science Agency, all Objectives (O1-O2).
Lead Organization/s	Office of Diversity and Inclusion, Office of the Director

Goal 8: Evaluate NSF Investments

<table>
<tr><td>Goal Statement</td><td colspan="2">Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.</td></tr>
<tr><td rowspan="2">Indicator and Target Measure, Milestone, or Deliverable</td><td>Revised FY 2016 Goal</td><td>FY 2017 Goal</td></tr>
<tr><td>By September 30, 2016, NSF will have developed three illustrative models of evaluation frameworks[1] in the following three areas: (1) investments in the development of U.S. science and engineering human capital, (2) investments in established NSF-wide priorities, and (3) long-term strategic investments.</td><td>By September 30, 2017, NSF will have developed seven additional evaluation frameworks. The Evaluation and Assessment Capability will work with at least seven programs (one in each directorate) to develop evaluation frameworks to be included in program management plans. This effort will build on what was learned in developing illustrative examples in FY 2016.</td></tr>
<tr><td>Description</td><td colspan="2">The mission of the EAC is to enable NSF to consistently evaluate the impacts of its investments, make more data-driven decisions, and establish a culture of evidence-based planning and policy-making. In FY 2016, EAC will develop plans for continuous program and portfolio improvement, informed by activities carried out in the three investment areas. These illustrative examples will be the first step to scale up the number of evaluation frameworks incorporated in program management plans in FY 2017:

1. Investments in the development of U.S. STEM human capital (for example, GRFP, REU). For this example, the EAC will develop at least one evaluation framework for longitudinal analysis rather than a cross-sectional evaluation of investments in human capital.
2. Investments in established NSF-wide priorities (for example, INFEWS, UtB). The EAC will work with program officers and other stakeholders to develop and include standard evaluation framework language in the management plan of at least one program in a priority area.
3. Long-term strategic investments (for example, I-Corps™, EPSCoR). The EAC will develop an evaluation framework for programmatic evaluation of at least one established long-term strategic investment.

In FY 2017, EAC will expand its efforts for continuous program and portfolio improvement, by working with programs across NSF to help them incorporate evaluation frameworks into their management plans.</td></tr>
<tr><td>Trend Information</td><td colspan="2">This is a revised performance goal in FY 2016 that replaces the goal published in the FY 2016 Budget.</td></tr>
</table>

[1] NSF defines evaluation frameworks to include, among other tasks, the articulation of (1) criteria for what constitutes evidence, (2) processes and methods for obtaining such evidence, and (3) how that evidence can be analyzed, synthesized, and used to determine both the direction and degree of progress towards desired objectives in complex adaptive situations. NSF's objective is to develop flexible and context dependent frameworks suitable for evaluating investments in all types of research and education.

Strategic Alignment	Strategic Goal 1: Transform the Frontiers of Science and Engineering, all Objectives (O1-O3). Strategic Goal 2: Stimulate Innovation and Address Societal Needs through Research and Education, all Objectives (O1-O2). Strategic Goal 3: Excel as a Federal Science Agency, all Objectives (O1-O2).
Lead Organization/s	Office of Integrative Activities, Office of the Director

Goal 9: Increase the Percentage of panelists participating in merit review virtually

<table>
<tr><td>Goal Statement</td><td colspan="2">Increase the percentage of proposal review panelists that participate virtually while maintaining the quality of the merit review process.</td></tr>
<tr><td rowspan="2">Indicator and Target Measure, Milestone, or Deliverable</td><td>Revised FY 2016 Goal</td><td>FY 2017 Goal</td></tr>
<tr><td>By September 30, 2016, at least 28 percent of merit review panelists will participate virtually.</td><td>By September 30, 2017, at least 28 percent of merit review panelists will participate virtually.</td></tr>
<tr><td>Description</td><td colspan="2">The merit review process is NSF’s most critical business function. Increased proposal submissions without attendant increases in staff have resulted in increased workload for staff and reviewers. Virtual participation can be an effective mechanism to improve efficiency.</td></tr>
<tr><td>Trend Information</td><td colspan="2">This is a revised performance goal for FY 2016 that replaces the goal published in the FY 2016 Budget. The table below shows trend information for virtual panel participation. The percentage of panelists participating virtually increased dramatically in FY 2013 as NSF piloted approaches to virtual panels. In FY 2014, the rate of increase slowed. In FY 2015, there was a decrease in virtual panel participation to below FY 2013 levels.

<table>
<tr><th>Fiscal Year</th><th>Virtual Panelists</th><th>Total Panelists</th><th>Percentage</th></tr>
<tr><td>2011</td><td>742</td><td>18,865</td><td>3.9%</td></tr>
<tr><td>2012</td><td>1,199</td><td>17,728</td><td>6.8%</td></tr>
<tr><td>2013</td><td>4,025</td><td>16,835</td><td>23.9%</td></tr>
<tr><td>2014</td><td>4,622</td><td>17,130</td><td>26.9%</td></tr>
<tr><td>2015</td><td>4,224</td><td>17,127</td><td>24.7%</td></tr>
</table>
Note. GRFP panelists are not included in table.</td></tr>
<tr><td>Strategic Alignment</td><td colspan="2">Strategic Goal 3: Excel as a Federal Science Agency,
Objective 2: Use effective methods and innovative solutions to achieve excellence in accomplishing the agency’s mission</td></tr>
<tr><td>Lead Organization/s</td><td colspan="2">Office of Integrative Activities, Office of the Director
NSF Chief Technology Officer (CTO), Office of the Director</td></tr>
</table>

OTHER INFORMATION

Management Reviews
Each quarter, NSF senior leadership reviews progress towards all performance goals of the agency in a data-driven review meeting led by the Chief Operating Officer and Performance Improvement Officer. The quarterly progress of the Agency Priority Goals (APGs) and performance goals are reviewed.

Alignment of Human Capital Efforts with Organizational Performance
In order to drive individual and organizational performance, NSF requires that the performance plans of all employees, executives, and the general workforce contain individual goals aligned with the agency's mission and strategic goals. NSF provides training and makes tools and templates available for all supervisors and employees on linking performance plans to agency mission, as well as providing assistance and training on the policies, processes, requirements, and timeframes for the development of performance plans and appraisals.

NSF also directly aligns its strategic human capital and accountability efforts to the agency goals identified in the NSF Strategic Plan. Agency performance goals currently outline specific human capital goals, and NSF uses HRStat as the agency reporting mechanism to articulate the nexus between NSF's strategic goals/objectives, including agency performance goals, and human capital initiatives at the agency. Senior leaders are briefed quarterly regarding the status of agency performance goals and the human capital initiatives aligned to those goals.

Strategies and Collaborations
No one standard strategy is used across NSF for achievement of goals. Goal leaders at NSF choose strategies tailored to their stakeholders' needs and their institutional capabilities. NSF goals often involve testing the impacts of new activities or new approaches to existing activities, so feedback mechanisms are built in. Use of analysis, evidence, and evaluation findings is also at the discretion of each individual goal leader, as is the decision to collaborate with other agencies or external entities or to invest in contract support for their activities. Performance at NSF is reviewed quarterly by NSF's Performance Improvement Officer, who reports on goal progress to NSF senior management.

NSF employs a balanced set of performance indicators, milestones, and measures. Due to the nature of NSF investments, the two mission-oriented goals, *Transform the Frontiers of Science and Engineering* and *Stimulate Innovation and Address Societal Needs through Research and Education*, tend to be output- or outcome-based. The management-oriented goal, *Excel as a Federal Science Agency*, contains efficiency and customer-service measures, but also output and outcome measures relating to long-term activities such as strategic human capital management and diversity and inclusion.

Advisory Committees and Committees of Visitors
Each directorate and office has an external advisory committee that typically meets twice a year to review and provide advice on program management, discuss current issues, and review and provide advice on the impact of policies, programs, and activities in the disciplines and fields encompassed by the directorate or office. In addition to directorate and office advisory committees, NSF has several committees that provide advice and recommendation on specific topics: astronomy and astrophysics; environmental research and education; equal opportunities in science and engineering; direction, development, and enhancements of innovations; polar programs; advanced cyberinfrastructure; international and integrative activities; the agency's merit review processes; and business and operations.

Committees of Visitors (COVs) are subcommittees of NSF directorate advisory committees. COV reviews provide NSF with external expert judgments in two areas: (1) assessments of the quality and integrity of program operations and program-level technical and managerial matters pertaining to proposal decisions;

and (2) comments on how the outputs and outcomes generated by awardees have contributed to the attainment of NSF's mission and strategic outcome goals. COV reviews are conducted at regular intervals of approximately three years for programs and offices that recommend or award grants, cooperative agreements, and/or contracts and whose main focus is the conduct or support of NSF research and education in science and engineering. Approximately one-third of NSF's divisions are assessed each year.

A COV typically consists of up to 20 external experts, selected to ensure independence, programmatic coverage, and geographic balance. COV members come from academia, industry, government, and the public sector. They meet for two or three days to review and assess program priorities, program management, and award accomplishments or outcomes. Each COV prepares a report and the division or program that is being reviewed must prepare a response to the COV recommendations. These reports and responses are submitted to the parent advisory committee and to the Director of NSF. All reports and responses are public and posted on NSF's website.[1]

In FY 2015, eight directorates and offices convened 16 Committees of Visitors (COVs), covering 12 divisions and nine programs. A list of the COVs performed is provided below. The chapters of the directorates also contain information on these COVs, as well as information on *ad hoc* reports.

[1] www.nsf.gov/od/oia/activities/cov/covs.jsp

Other Information

List of Committees of Visitors Meetings, FY 2014-FY 2017

DIR	**FY 2014**	**FY 2015**	**FY 2016 (planned)**	**FY 2017 (planned)**
BIO	Molecular and Cellular Biosciences Integrative Organismal Systems Emerging Frontiers	Environmental Biology	Biological Infrastructure	Molecular and Cellular Biosciences Integrative Organismal Systems
CISE	-	Computing and Communication Foundations Computer and Network Systems Information and Intelligent Systems	Advanced Cyberinfrastructure	-
EHR	Human Resource Development: ADVANCE	Research on Learning in Formal and Informal Settings Graduate Education: GK-12/IGERT/SfS Undergraduate Education: ATE Undergraduate Education: Noyce/S-STEM	EHR Core Research Undergraduate Education: TUES, STEP, WIDER, IUSE:EHR	Graduate Education Human Resource Development
ENG	Electrical, Communications and Cyber Systems Emerging Frontiers in Research and Innovation	Chemical, Bioengineering, Environmental and Transport Systems Civil, Mechanical and Manufacturing Innovations	Engineering, Education and Centers Industrial Innovation and Partnerships	Electrical, Communications and Cyber Systems Emerging Frontiers and Multidisciplinary Activities
GEO	Atmospheric and Geospace Sciences: Geospace Section Earth Sciences Ocean Sciences: Integrative Programs Section	Atmospheric & Geospace Sciences: NCAR and Facilities Section Ocean Sciences: Research and Education	Atmospheric and Geospace Sciences: programs TBD Polar Programs: programs TBD	Atmospheric and Geospace Sciences: programs TBD Earth Sciences: programs TBD Ocean Sciences: programs TBD
MPS	-	Astronomy Materials Research Physics	Chemistry Mathematical Sciences	-

DIR	**FY 2014**	**FY 2015**	**FY 2016 (planned)**	**FY 2017 (planned)**
SBE	-	Office of Multidisciplinary Activities Behavioral and Cognitive Sciences	Social and Economic Sciences	-
OIA and OISE (was OIIA)	International Science and Engineering	Experimental Program to Stimulate Competitive Research (EPSCoR)	Major Research Infrastructure	Science and Technology Centers International Science and Engineering

Evaluations and Research

Evaluations at NSF are currently performed at the discretion of the individual directorate, office, or program being evaluated. For discussion of how NSF uses planned, current, and recently completed evaluations in its program decisions, refer to individual directorate and office chapters. A list of the evaluations completed in FY 2015 follows, along with a list of selected high-impact events (workshops, symposia, or other meetings resulting in publications) reported by directorates. For more details about how the results of these specific evaluations or events are being used to shape agency decisions, see the chapter of the sponsoring directorate. For more information about program evaluation and collection and management of NSF programmatic data, see the NSF-Wide Investments chapter section on NSF's Evaluation and Assessment Capability.

External Evaluations Completed in FY 2015

DIR	Program, Topic, or Area Evaluated	Name of Evaluation	Evaluator	Link to report
EHR	Advancing Informal Science Learning (was Informal Science Education)	Evaluation of the Informal Science Education (ISE) Program	SRI International	Not Yet Available
EHR	Innovative Technology Experiences for Students and Teachers (ITEST)	Evaluation of the Innovative Technology Experiences for Students and Teachers (ITEST) Program	SRI International	Not Yet Available
EHR	National STEM Digital Library/ Distributed Learning (NSDL)	Evaluation of the National STEM Digital Library/Distributed Learning (NSDL) Program	Guardians of Honor	Not Yet Available
EHR	Research and Evaluation on Education in Science and Engineering (REESE)	Evaluation of the National Science Foundation's Research and Evaluation on Education in Science and Engineering (REESE) Program	Westat	Not Yet Available
GEO	Ocean Sciences	Sea Change: Decadal Survey of Ocean Sciences 2015-2025	National Research Council	www.nap.edu/catalog/21655
GEO	Antarctic and Southern Ocean research	A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research	National Academies of Sciences, Engineering, and Medicine	www.nap.edu/catalog/21741
MPS	Large Synoptic Survey Telescope	Optimizing the U.S. Ground-Based Optical and Infrared Astronomy System	National Research Council	www.nap.edu/catalog/21722
SBE	Replicability	Social, Behavioral, and Economic Sciences Perspectives on Robust and Reliable Science	Subcommittee on Replicability in Science, SBE AC	www.nsf.gov/sbe/AC_Materials/SBE_Robust_and_Reliable_Research_Report.pdf

Selected Meetings, Symposia, and Workshops in FY 2015

DIR	Workshop Name	Link to report
BIO	The Nuts and Bolts of Bioengineered Systems: A workshop on Standards in Synthetic Biology	http://147.156.205.24/synbioworkshop/?tag=synbioworkshop
BIO	NIMBioS: National Institute of Mathematical Biosynthesis: A Workshop on Computational Advances in Microbiome Research (CAMR)	www.nimbios.org/workshops/WS_microbiome
BIO	The Pathway to a Roadmap: Phytobiomes 2015: Designing a New Paradigm for Crop Improvement	www.phytobiomes.org/activities/Pages/Phytobiomes-2015.aspx
BIO	Physics of Wear, Tear, Aging and Failure in Living and Nonliving Systems	http://physicsoflivingsystems.org/workshops/physicsofweartearaging/
BIO	Interactive Mentoring Activities for Grantsmanship Enhancement	http://grantome.com/grant/NSF/MCB-1513415
BIO	9th Annual q-bio conference	q-bio.org/wiki/The_Ninth_q-bio_Conference
CSE	A New Age of Computing and the Brain	http://cra.org/ccc/wp-content/uploads/sites/2/2014/12/BRAIN-Report.pdf
CSE	Toward a Science of Autonomy for Physical Systems	http://cra.org/ccc/wp-content/uploads/sites/2/2015/07/Science-of-Autonomy-June-2015.pdf
CSE	Continuing Innovation in Information Technology: A Workshop	http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_086055
ENG	Frontiers of Additive Manufacturing Research and Education	www.wilsoncenter.org/sites/nsfamenv/index.html
ENG	Advanced Manufacturing for the Oil and Gas Energy Industry	http://ise.tamu.edu/nsf2014/PDFs/NSF-OGWorkshop-Report_Feb_2015.pdf
ENG	Rebooting the IT Revolution: A Call to Action	www.src.org/newsroom/rebooting-the-it-revolution.pdf
MPS, ENG, CISE	Rise of Data in Materials Research	http://riseofdata.org/
MPS	Enabling Resiliency in Energy Water and Food Systems for Society: Addressing the Scientific, Technological and Societal Challenges of the Energy, Water and Food Nexus	www.nsf.gov/mps/che/workshops/uarizona_few_nexus_workshop_report_final.pdf
MPS	Closing the Human Phosphorous Cycle Workshop	www.nsf.gov/mps/che/workshops/phosphorus_cycle_report_final.pdf
MPS	Evidence-Based Practices for Broadening Participation in the Chemical Sciences	http://csp.umn.edu/wp-content/uploads/2015/07/Final-Report-CCI-Diversity-Forum.pdf
MPS	DOE/NSF Materials Genome Initiative (MGI) Principal Investigators' Meeting	www.orau.gov/mgi2015
MPS	Mathematical Sciences Internships: Building Career Pathways	www.ipam.ucla.edu/reports/2015-nsf-ipam-mathematical-sciences-internship-workshop-report
MPS	Mathematical Sciences Challenges in Quantum Information	www.sites.google.com/site/mathqinfo2015/home
MPS	Interdisciplinary Approaches to Biomedical Data Science Challenges	www.samsi.info/workshop/interdisciplinary-approaches-biomedical-data-science-challenges-samsi-innovations-lab-july-

Data Verification and Validation

It is NSF's practice to follow Government Accountability Office (GAO) guidance and engage external contractors to conduct an independent validation and verification (V&V) review of its annual performance information, data, and processes. The guidance from GAO indicates that agencies should "…describe the means the agency will use to verify its performance data…" and "…provide confidence that [their] performance information will be credible."[2] NSF will continue this process in FY 2016 and FY 2017.

In FY 2015, IBM Global Business Services (IBM) assessed the validity of NSF data and verified the reliability of the methods used to collect, process, maintain, and report that data, and reviewed NSF's information systems based on GAO standards for application controls. IBM's FY 2015 report concluded:

> Based on the FY 2015 Verification and Validation (V&V) review, IBM was able to fully verify the reliability of the processes and validate the accuracy of results reported for all of NSF's eleven[3] annual performance goals.
>
> Overall, IBM verifies that NSF relies on sound business practices, internal controls, and manual checks of system queries to ensure accurate performance reporting. NSF maintains adequate documentation of its processes and data to allow for an effective V&V review. Based on the V&V assessment, IBM has confidence in the systems, policies, and procedures used by NSF to calculate results for its performance measures that contained targets. NSF continues to take concerted steps to improve the quality of its systems and data. IBM confirms NSF's commitment to ensuring the accuracy of its reported GPRA results, and the reliability of its processes for collecting, processing, maintaining, and reporting data for its performance goals.[4]

The data and information required to measure progress towards NSF's performance goals fall into three broad categories.

1. NSF automated administrative systems. Performance monitoring can be a valuable secondary function of such systems. Reporting can include data from systems that:
   Store and approve publications such as solicitations announcements, and Dear Colleague Letters;
   - Collect transactional data about proposal and award management;
   - Perform financial transactions;
   - Store human resources data; or
   - Permit keyword search of abstract or full texts of proposals and awards.

   The data were used either directly or for achieving milestones that involve the writing of a report. While not all goals require a high level of accuracy, data from these systems are highly reliable.

2. Reports on internal activities. Milestone achievement is often determined from review of records of certain activities and events. Records of this sort tend to be compiled from review of the evidence provided by goal leaders.

3. Data requests of external parties. Qualitative or quantitative information is solicited directly from awardees.

[2] GAO, The Results Act: An Evaluator's Guide to Assessing Agency Annual Performance Plans, GAO/GGD-10.1.20 (Washington, D.C.: April 1998), pp. 40-41.
[3] One FY 2014 goal, Data-Driven Management Reviews (Goal 10 in FY 2014), did not have complete data at the time of the FY 2014 V&V and was instead V&V'd in FY 2015.
[4] IBM Global Business Services, *National Science Foundation Performance Measurement Verification and Validation Report, Fourth Quarter Final Report Fiscal Year 2015*. October 23, 2015.

Management Challenges
A discussion of agency management challenges can be found in the FY 2015 Agency Financial Report.[5]

Burden Reduction/Unnecessary Plans and Reports to Congress
The GPRA Modernization Act of 2010 requires that agencies identify which of the plans and reports they provide to Congress are outdated or duplicative of other required plans and reports. The complete list of reports that NSF suggested for consolidation or elimination can be found on performance.gov.

Lower-Priority Program Activities
The President's Budget identifies the lower-priority program activities, where applicable, as required under the GPRA Modernization Act (31 U.S.C. 1115(b)(10)). The public can access the volume at www.whitehouse.gov/omb/budget.

Use of Non-Federal Parties
No non-federal parties were involved in preparation of this Annual Performance Report.

Classified Appendices Not Available to the Public
None

[5] www.nsf.gov/pubs/2016/nsf16002/

Other Information

TECHNICAL INFORMATION

FY 2017 Appropriations Language

National Science Foundation

RESEARCH AND RELATED ACTIVITIES

For necessary expenses in carrying out the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), and Public Law 86-209 (42 U.S.C. 1880 et seq.); services as authorized by section 3109 of title 5, United States Code; maintenance and operation of aircraft and purchase of flight services for research support; acquisition of aircraft; and authorized travel; $6,079,430,000, to remain available until September 30, 2018, of which not to exceed $544,000,000 shall remain available until expended for polar research and operations support, and for reimbursement to other Federal agencies for operational and science support and logistical and other related activities for the United States Antarctic program: *Provided*, That receipts for scientific support services and materials furnished by the National Research Centers and other National Science Foundation supported research facilities may be credited to this appropriation.

EDUCATION AND HUMAN RESOURCES

For necessary expenses in carrying out science, mathematics and engineering education and human resources programs and activities pursuant to the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), including services as authorized by section 3109 of title 5, United States Code, authorized travel, and rental of conference rooms in the District of Columbia, $898,870,000, to remain available until September 30, 2018.

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

For necessary expenses for the acquisition, construction, commissioning, and upgrading of major research equipment, facilities, and other such capital assets pursuant to the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.), including authorized travel, $193,120,000, to remain available until expended.

AGENCY OPERATIONS AND AWARD MANAGEMENT

For agency operations and award management necessary in carrying out the National Science Foundation Act of 1950 (42 U.S.C. 1861 et seq.); services authorized by section 3109 of title 5, United States Code; hire of passenger motor vehicles; uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; rental of conference rooms in the District of Columbia; and reimbursement of the Department of Homeland Security for security guard services; $373,020,000: *Provided*, That not to exceed $8,280 is for official reception and representation expenses: *Provided further*, That contracts may be entered into under this heading in fiscal year 2017 for maintenance and operation of facilities and for other services to be provided during the next fiscal year; *Provided further*, That of the amount provided for costs associated with the acquisition, occupancy, and related costs of new headquarters space, not more than $40,700,000 shall remain available until expended

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General as authorized by the Inspector General Act of 1978, $15,200,000, of which $400,000 shall remain available until September 30, 2018.

OFFICE OF THE NATIONAL SCIENCE BOARD

For necessary expenses (including payment of salaries, authorized travel, hire of passenger motor vehicles, the rental of conference rooms in the District of Columbia, and the employment of experts and consultants under section 3109 of title 5, United States Code) involved in carrying out section 4 of the National Science Foundation Act of 1950 (42 U.S.C 1863) and Public Law 86-209 (42 U.S.C. 1880 et seq.), $4,380,000: *Provided*, That not to exceed $2,500 shall be available for official reception and representation expenses.

ADMINISTRATIVE PROVISION

Not to exceed 5 percent of any appropriation made available for the current fiscal year for the National Science Foundation in this Act may be transferred between such appropriations, but no such appropriation shall be increased by more than 15 percent by any such transfers. Any transfer pursuant to this section shall be treated as a reprogramming of funds under section 505 of this Act and shall not be available for obligation except in compliance with the procedures set forth in that section.

SUMMARY OF FY 2017 BUDGETARY RESOURCES BY ACCOUNT

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
RESEARCH AND RELATED ACTIVITIES					
Appropriation	$5,933.65	$6,033.65	$6,079.43	$45.78	0.8%
Unobligated Balance Available Start of Year	57.66	10.08		-10.08	
Unobligated Balance Available End of Year	-10.08				
Adjustments to Prior Year Accounts[1]	60.35				
Total Budgetary Resources	$6,041.57	$6,043.73	$6,079.43	$35.70	0.6%
EDUCATION AND HUMAN RESOURCES					
Appropriation	$866.00	$880.00	$898.87	$18.87	2.1%
Unobligated Balance Available Start of Year	16.37	2.63		-2.63	
Unobligated Balance Available End of Year	-2.63				
Adjustments to Prior Year Accounts[1]	6.59				
Total Budgetary Resources	$886.33	$882.63	$898.87	$16.24	1.8%
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION					
Appropriation	$200.76	$200.31	$193.12	-$7.19	-3.6%
Unobligated Balance Available Start of Year	0.39	58.06		-58.06	
Unobligated Balance Available End of Year	-58.06				
Adjustments to Prior Year Accounts[1]	1.67				
Total Budgetary Resources	$144.76	$258.37	$193.12	-$65.25	-25.3%
AGENCY OPERATIONS AND AWARD MANAGEMENT					
Appropriation	$325.00	$330.00	$373.02	$43.02	13.0%
Unobligated Balance Available Start of Year	-	18.11		-18.11	
Unobligated Balance Available End of Year	-18.11				
Adjustments to Prior Year Accounts[1]	-0.33				
Total Budgetary Resources	$306.56	$348.11	$373.02	$24.91	7.2%
NATIONAL SCIENCE BOARD					
Appropriation	$4.37	$4.37	$4.38	$0.01	0.2%
Unobligated Balance - Expired	-0.22				
Total Budgetary Resources	$4.15	$4.37	$4.38	$0.01	0.2%
OFFICE OF INSPECTOR GENERAL					
Appropriation	$14.43	$15.16	$15.20	$0.04	0.3%
Unobligated Balance Available Start of Year	0.40	0.17		-0.17	
Unobligated Balance Available End of Year	-0.17				
Adjustments to Prior Year Accounts[1]	-0.06				
Total Budgetary Resources	$14.60	$15.33	$15.20	-$0.13	-0.8%
TOTAL DISCRETIONARY, NATIONAL SCIENCE FOUNDATION	$7,397.97	$7,552.54	$7,564.02	$11.48	0.2%

Totals may not add due to rounding.

[1]Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

SUMMARY OF FY 2017 BUDGETARY RESOURCES BY ACCOUNT

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Percent
RESEARCH AND RELATED ACTIVITIES, MANDATORY					
Appropriation, Mandatory	-	-	$346.01	$346.01	N/A
Unobligated Balance Available Start of Year	-	-		-	
Sequestration Previously Unavailable	-	-			
Sequestration Pursuant OMB M-13-06	-				
Unobligated Balance Available End of Year	-				
Adjustments to Prior Year Accounts[1]	-				
Total Budgetary Resources	-	-	$346.01	$346.01	N/A
EDUCATION AND HUMAN RESOURCES, NON-H-1B MANDATORY					
Appropriation, Mandatory	-	-	$53.99	$53.99	N/A
Unobligated Balance Available Start of Year	-	-		-	
Sequestration Previously Unavailable	-	-			
Sequestration Pursuant OMB M-13-06	-				
Unobligated Balance Available End of Year	-				
Adjustments to Prior Year Accounts[1]	-				
Total Budgetary Resources	-	-	$53.99	$53.99	N/A
EDUCATION AND HUMAN RESOURCES, H-1B					
Appropriation, Mandatory (H1-B Non-Immigrant Petitioner Fees)	$140.76	$100.00	$100.00	-	-
Unobligated Balance Available Start of Year	108.35	116.02		-116.02	
Sequestration Previously Unavailable	9.54	7.30		-7.30	
Sequestration Pursuant OMB M-13-06	-7.30				
Unobligated Balance Available End of Year	-116.02				
Adjustments to Prior Year Accounts[1]	3.84				
Total Budgetary Resources	$139.17	$223.32	$100.00	-$123.32	-55.2%
DONATIONS					
Mandatory Programs (Special or Trust Fund)	$34.87	$35.00	$35.00	-	-
Unobligated Balance Available Start of Year	27.85	29.12		-29.12	
Unobligated Balance Available End of Year	-29.12				
Adjustments to Prior Year Accounts[1]	1.21				
Total Budgetary Resources	$34.81	$64.12	$35.00	-$29.12	-45.4%
TOTAL, NATIONAL SCIENCE FOUNDATION	$7,571.95	$7,839.98	$8,099.02	$259.04	3.3%

Totals may not add due to rounding.

[1]Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

NSF FY 2017 REQUEST FUNDING BY PROGRAM

(Dollars in Millions)

PROGRAM	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	Percent
BIOLOGICAL SCIENCES (BIO)							
BIOLOGICAL INFRASTRUCTURE	$144.14	$144.68	$135.74	-	$135.74	-$8.94	-6.2%
EMERGING FRONTIERS	98.22	105.61	112.65	44.79	157.44	51.83	49.1%
ENVIRONMENTAL BIOLOGY	143.76	144.03	145.17	-	145.17	1.14	0.8%
INTEGRATIVE ORGANISMAL SYSTEMS	215.12	214.32	215.40	-	215.40	1.08	0.5%
MOLECULAR & CELLULAR BIOSCIENCES	134.95	135.53	136.77	-	136.77	1.24	0.9%
TOTAL, BIO	**$736.19**	**$744.17**	**$745.73**	**$44.79**	**$790.52**	**$46.35**	**6.2%**
COMPUTER & INFORMATION SCIENCE & ENGINEERING (CISE)							
ADVANCED CYBERINFRASTRUCTURE	$219.19	$222.30	$222.92	$13.39	$236.31	$14.01	6.3%
COMPUTING & COMMUNICATION FOUNDATIONS	195.69	194.23	194.77	11.70	206.47	12.24	6.3%
COMPUTER & NETWORK SYSTEMS	231.45	231.10	231.74	13.92	245.66	14.56	6.3%
INFORMATION & INTELLIGENT SYSTEMS	194.58	194.90	195.46	11.74	207.20	12.30	6.3%
INFORMATION TECHNOLOGY RESEARCH	92.07	93.29	93.54	5.62	99.16	5.87	6.3%
TOTAL, CISE	**$932.98**	**$935.82**	**$938.43**	**$56.37**	**$994.80**	**$58.98**	**6.3%**
ENGINEERING (ENG)							
CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, & TRANSPORT SYSTEMS	$180.40	$183.82	$187.18	$11.24	$198.42	$14.60	7.9%
CIVIL, MECHANICAL, & MANUFACTURING INNOVATION	225.55	216.39	220.67	13.25	233.92	17.53	8.1%
ELECTRICAL, COMMUNICATIONS, & CYBER SYSTEMS	118.97	113.95	115.80	6.97	122.77	8.82	7.7%
INDUSTRIAL INNOVATION & PARTNERSHIPS	227.26	239.93	254.17	14.73	268.90	28.97	12.1%
[SBIR/STTR]	*[177.11]*	*[188.56]*	*[201.67]*	*[11.59]*	*[213.26]*	*[24.70]*	*[13.1%]*
ENGINEERING EDUCATION & CENTERS	117.95	107.61	113.50	6.82	120.32	12.71	11.8%
EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES	53.41	54.49	55.09	3.31	58.40	3.91	7.2%
TOTAL, ENG	**$923.53**	**$916.19**	**$946.41**	**$56.32**	**$1,002.73**	**$86.54**	**9.4%**

NSF FY 2017 REQUEST FUNDING BY PROGRAM

(Dollars in Millions)

PROGRAM	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	Percent
GEOSCIENCES (GEO)							
ATMOSPHERIC & GEOSPACE SCIENCES	$252.18	$253.67	$253.67	$14.25	$267.92	$14.25	5.6%
EARTH SCIENCES	178.31	179.39	179.39	12.29	191.68	12.29	6.9%
INTEGRATIVE & COLLABORATIVE EDUCATION AND RESEARCH	84.22	83.74	84.77	10.18	94.95	11.22	13.4%
OCEAN SCIENCES	361.31	359.89	359.89	19.53	379.42	19.53	5.4%
POLAR PROGRAMS	443.02	441.85	441.84	23.02	464.86	23.01	5.2%
[US Antarctic Logistical Support Activities]	*[67.52]*	*[67.52]*	*[67.52]*	*[-]*	*[67.52]*	*[-]*	*[-]*
TOTAL, GEO	**$1,319.04**	**$1,318.54**	**$1,319.56**	**$79.27**	**$1,398.83**	**$80.30**	**6.1%**
MATHEMATICAL & PHYSICAL SCIENCES (MPS)							
ASTRONOMICAL SCIENCES	$245.23	$246.73	$247.73	$14.88	$262.61	$15.88	6.4%
CHEMISTRY	246.29	246.31	247.31	14.85	262.16	15.85	6.4%
MATERIALS RESEARCH	337.62	310.03	311.03	18.68	329.71	19.68	6.3%
MATHEMATICAL SCIENCES	235.43	234.05	235.05	14.12	249.17	15.12	6.5%
PHYSICS	276.10	277.03	278.53	16.73	295.26	18.23	6.6%
MULTIDISCIPLINARY ACTIVITIES	35.65	35.00	35.41	2.13	37.54	2.54	7.3%
TOTAL, MPS	**$1,376.32**	**$1,349.15**	**$1,355.06**	**$81.39**	**$1,436.45**	**$87.30**	**6.5%**
SOCIAL, BEHAVIORAL & ECONOMIC SCIENCES (SBE)							
BEHAVIORAL AND COGNITIVE SCIENCES	$97.03	$95.06	$95.06	$7.02	$102.08	$7.02	7.4%
SOCIAL AND ECONOMIC SCIENCES	98.36	98.18	98.18	7.24	105.42	7.24	7.4%
MULTIDISCIPLINARY ACTIVITIES	29.86	28.20	27.41	2.10	29.51	1.31	4.6%
NATIONAL CENTER FOR SCIENCE & ENGINEERING STATISTICS	50.94	50.76	51.76	-	51.76	1.00	2.0%
TOTAL, SBE	**$276.19**	**$272.20**	**$272.41**	**$16.36**	**$288.77**	**$16.57**	**6.1%**
OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE)	**$48.46**	**$49.10**	**$49.10**	**$2.95**	**$52.05**	**$2.95**	**6.0%**

NSF FY 2017 REQUEST FUNDING BY PROGRAM

(Dollars in Millions)

PROGRAM	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)[1]	FY 2017 Request	FY 2017 Request Change Over FY 2016 Estimate Amount	Percent
INTEGRATIVE ACTIVITIES (IA)							
EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCOR)	165.46	160.00	162.13	8.56	170.69	10.69	6.7%
INTEGRATIVE ACTIVITIES	262.00	287.06	289.17	-	289.17	2.11	0.7%
[Major Research Instrumentation (MRI)]	*[74.22]*	*[75.69]*	*[90.00]*	*[-]*	*[90.00]*	*[14.31]*	*[18.9%]*
TOTAL, IA	**$427.46**	**$447.06**	**$451.30**	**$8.56**	**$459.86**	**$12.80**	**2.9%**
UNITED STATES ARCTIC RESEARCH COMMISSION	**$1.41**	**$1.43**	**$1.43**	**-**	**$1.43**	**-**	**-**
TOTAL, RESEARCH AND RELATED ACTIVITIES	**$6,041.57**	**$6,033.65**	**$6,079.43**	**$346.01**	**$6,425.44**	**$391.79**	**6.5%**
EDUCATION & HUMAN RESOURCES (EHR)							
GRADUATE EDUCATION	$286.14	$278.48	$305.26	-	$305.26	$26.78	9.6%
HUMAN RESOURCE DEVELOPMENT	143.90	150.23	153.09	2.80	155.89	5.66	3.8%
RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS	227.20	222.75	201.84	47.44	249.28	26.53	11.9%
UNDERGRADUATE EDUCATION	229.08	228.54	238.68	3.75	242.43	13.89	6.1%
TOTAL, EDUCATION & HUMAN RESOURCES	**$886.33**	**$880.00**	**$898.87**	**$53.99**	**$952.86**	**$72.86**	**8.3%**
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION	**$144.76**	**$200.31**	**$193.12**	**-**	**$193.12**	**-$7.19**	**-3.6%**
AGENCY OPERATIONS AND AWARD MANAGEMENT	**$306.56**	**$330.00**	**$373.02**	**-**	**$373.02**	**$43.02**	**13.0%**
OFFICE OF THE INSPECTOR GENERAL	**$14.60**	**$15.16**	**$15.20**	**-**	**$15.20**	**$0.04**	**0.3%**
NATIONAL SCIENCE BOARD	**$4.15**	**$4.37**	**$4.38**	**-**	**$4.38**	**$0.01**	**0.2%**
TOTAL, NATIONAL SCIENCE FOUNDATION	**$7,397.97**	**$7,463.49**	**$7,564.02**	**$400.00**	**$7,964.02**	**$500.53**	**6.7%**

Totals may not add due to rounding.

[1] Includes only new mandatory funding. Excludes H-1B Nonimmigrant Petitioner mandatory funds.

OBJECT CLASSIFICATION
NSF Consolidated Obligations
(Dollars in Millions)

Object Class Code	Standard Title	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)[1]	FY 2017 Request (Mandatory)[2]	FY 2017 Request
11.1	Full-time permanent	$153	$165	$166	-	$166
11.3	Other than full-time permanent	10	10	10	-	10
11.5	Other personnel compensation	2	2	2	-	2
11.8	Special personal service payment	1	1	1	-	1
	Total personnel compensation	166	178	179	-	179
12.1	Civilian personnel benefits	49	53	55	-	55
21.0	Travel and transportation of persons	23	22	22	-	22
23.1	Rental payments	34	34	47	-	47
23.3	Communications, utilities, and miscellaneous charges	2	4	5	-	5
25.1	Advisory and assistance services	185	191	205	-	205
25.2	Other services	28	26	28	-	28
25.3	Purchases of goods and services from Government accounts	86	89	91	-	91
25.4	Operation and maintenance of facilities	273	270	275	-	275
25.5	Research and development contracts	6	6	5	-	5
26.0	Operation and maintenance of equipment	1	-	2	-	2
26.0	Supplies and materials	2	4	5	-	5
31.0	Equipment	3	20	14	-	14
41.0	Grants, subsidies, and contributions	6,714	6,943	6,766	400	7,166
	Total, Direct obligations [3,4]	$7,572	$7,840	$7,699	$400	$8,099

Totals may not add due to rounding.

[1]This table reflects recent updates and may not match what is shown in the *Budget of the United States Government, Fiscal Year 2017*.

[2]Includes only the fiscal year 2017 new mandatory authority.

[3]Includes mandatory obligations, but excludes obligations for reimbursable accounts.

[4]Actual and estimated reimbursble obligations for fiscal years 2015 through 2017 total $6 million, $10 million, and $10 million for Agency Operations and Award Management, $95 million, $120 million, and $120 million for Research and Related Activities, and $5 million, $15 million, and $15 million in Education and Human Resources.

REIMBURSABLE ACTIVITY

Reimbursements for the Research and Related Activities Appropriation and the Education and Human Resources Appropriation are realized from other federal agencies that have entered into interagency agreements with the Foundation. NSF enters into agreements (including Memoranda of Understanding) with other U.S. government agencies, as authorized by the NSF Act, 42 U.S.C. 1870 (c) and the Economy Act: 31 U.S.C. 1535, under which NSF assumes some responsibility for activities supported by these agencies. These activities can include jointly funded projects and programs, support of research operations and logistics, and access to NSF supported research facilities.

Reimbursements by Agency

(Dollars in Millions)

DEPARTMENT/AGENCY	FY 2015 Actual
DEFENSE	
Air Force	$7.8
Army	5.6
Other DoD (DARPA, NSA & Intelligence)	10.5
Subtotal, DoD	$24.0
Agriculture	0.9
Commerce (Including Census, NOAA, & NIST)	17.2
Energy	6.8
Health & Human Services	26.3
Homeland Security	2.6
Interior	0.7
Justice	0.9
NASA	13.3
State	0.6
Transportation	5.7
OTHER (less than $500,000)	1.2
TOTAL REIMBURSEMENTS	**$100.2**

Totals may not add due to rounding

Consistent with applicable legislation and GAO decisions, agreements include reimbursement for costs that are incurred in the management and administration of these awards.

In FY 2015, the largest portion of NSF's reimbursable activity came from joint activities with the Department of Defense (24.0 percent), the Department of Health and Human Services (26.3 percent), the Department of Commerce (including the Census Bureau, and the National Oceanic and Atmospheric Administration, and the National Institute of Standards and Technology) (17.2 percent), the Department of Energy (6.8 percent), the National Aeronautics and Space Administration (13.3 percent), the Department of Transportation (5.7 percent). Reimbursable activities with the Department of Defense were largely for the management of the National Center for Atmospheric Research. Reimbursable activities with the Department of Health and Human Services are for non-medical biological research.

NSF PERSONNEL SUMMARY OF PERMANENT APPOINTMENTS

Statutory Pay Systems	FY 2015 Actual Appointments
ES	65
AD	329
GS/GM-15	89
GS/GM-14	181
GS/GM-13	139
GS-12	100
GS-11	86
GS-10	5
GS-9	65
GS-8	15
GS-7	39
GS-6	3
GS-5	2
GS-4	-
Subtotal, GS/GM	724
Total, Permanent Appointments	1,118
Average Salary	$123,099

All data are for permanent appointments.

EXPLANATION OF FY 2015 CARRYOVER INTO FY 2016 BY ACCOUNT

The National Science Foundation's (NSF) total unobligated balance of $235.34 million ($90.20 million for Discretionary accounts, including $1.15 million for Incoming Interagency Reimbursable Agreements, and $145.14 million for Mandatory accounts) is described below.

DISCRETIONARY

Within the **Research and Related Activities (R&RA)** account, $11.17 million (including $1.09 million in reimbursable funds) was carried over into FY 2016.

- Directorate for Geosciences Polar Programs (no-year funding)
  - Amount: $5.05 million
  - Reason: These funds are recoveries from prior year obligations.
  - Anticipated Obligation: FY 2016 Quarter 2

- Office of Integrative Activities
  - Amount: $2.55 million
  - Reason: Carryover balance is for the Major Research Instrumentation Program. Several MRI awards were not ready for obligation before the close of FY 2015. Funds will be used for FY 2016 awards.
  - Anticipated Obligation: FY 2016 Quarter 2

- National Coordination Office for Networking and Information Technology Research and Development (NCO/NITRD)
  - Amount: $439,100
  - Reason: Funding provided for the operations of NCO/NITRD.
  - Anticipated Obligation: FY 2016 Quarter 2

- National Nanotechnology Coordination Office (NNCO)
  - Amount: $22,000
  - Reason: Funding provided for the operations of NNCO.
  - Anticipated Obligation: FY 2016 Quarter 2

- The remaining R&RA carryover of $2.02 million consists of funds from throughout the Foundation for projects that were not ready for obligation in FY 2015.

Within the **Education and Human Resources (EHR)** account, $2.69 million (including $62,144 in reimbursable funds) was carried over into FY 2016.

- Excellence Awards in Science and Engineering (EASE)
  - Amount: $2.61 million
  - Reason: Approximately $2.33 million for the Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) program was carried over into FY 2016. The FY 2014 awardees were not recognized in FY 2015 and have been scheduled to be recognized in FY 2016 along with the FY 2015 awardees.

    - Reason: $275,682 for the Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM) was carried over into FY 2016. The FY 2014 and 2015 awardees were not recognized in FY 2015 and are scheduled to be recognized in FY 2016.
    - Anticipated Obligation: FY 2016 Quarter 2

- The remaining $23,041 are residual funds from various EHR accounts.

Within the **Major Research Equipment and Facilities Construction** no-year account, $58.06 million was carried over into FY 2016.

- National Ecological Observatory Network (NEON)
    - Amount: $56.0 million
    - Reason: FY 2015 obligations were limited in connection with the construction management transition. For additional information, please see the NEON section of the MREFC Chapter.
    - Anticipated Obligation: FY 2016 Quarter 3

- The remaining $2.06 million in the MREFC account is due to a settlement of $1.67 million for the Large Hadron Collider project; and $390,691 in residual funds from the Advanced Laser Interferometer Gravitational Wave Observatory.

Within the **Agency Operations and Award Management** (AOAM) no-year account, $18.11 million was carried over into FY 2016.

- NSF Headquarters Relocation
    - Amount: $18.11 million
    - Reason: Obligations planned for FY 2015 have been shifted to FY 2016.
    - Anticipated Obligation: FY 2016 Quarter 2

Within the **Office of Inspector General (OIG)** two-year account, $171,000 was carried over into FY 2016.

- Office of the Inspector General
    - Amount: $171,000
    - Reason: Funds are expected to be used to procure audit and forensic contracts. The selection of awards and institutions to be audited will require careful preparation and is subject to changing circumstances and new information that may require additional time to process.
    - Anticipated Obligation: FY 2016 Quarter 2

MANDATORY

- Innovation Technology Experiences for Students (ITEST)
    - Amount: $29.96 million
    - Reason: Within the H-1B Nonimmigrant Petitioner account, approximately $29.96 million was carried over for the NSF Innovative Technology Experiences for Students (ITEST). Since NSF receives the largest payments of H-1B visa fees in August and September, there was insufficient time to obligate the receipts on awards before the end of the fiscal year.
    - Anticipated Obligation: FY 2016 Quarter 2

- Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)
    - Amount: $86.06 million

- Reason: Within the H-1B Nonimmigrant Petitioner account, approximately $86.06 million was carried over for the NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program. Since NSF receives the largest payments of H-1B visa fees in August and September, there was insufficient time to obligate the receipts on awards before the end of the fiscal year.
- Anticipated Obligation: FY 2016 Quarter 2

Within the **Donations** account, $29.12 million was carried over into FY 2016. Donations were received from foreign governments, organizations, and individuals to fund various cooperative efforts in science, research, and education.

Discretionary and Mandatory Accounts
Distribution of FY 2015 Carryover into FY 2016
(Dollars in Millions)

Discretionary Accounts	**Amount**
Research and Related Activities	$11.17
Education and Human Resources	2.69
Major Research Equipment and Facilities Construction	58.06
Agency Operations and Award Management	18.11
Office of Inspector General	0.17
Subtotal	**90.20**
Mandatory Accounts	
H-1B Non-Immigrant Petitioner	116.02
Donations (Special or Trust Fund)	29.12
Subtotal	**145.14**
TOTAL	**$235.34**

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE FOUNDATION

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	$4,973.90	$4,940.92	$4,946.81	$310.75	$5,257.56
Applied Research	695.83	751.53	761.02	52.22	813.24
Subtotal, Conduct of R&D	5,669.73	5,692.45	5,707.83	362.97	6,070.80
Physical Assets					
Research and Development Facilities	152.37	207.84	200.65	0.45	201.10
Research and Development Major Equipment	167.64	216.37	251.74	6.06	257.80
Subtotal, R&D Facilities & Major Equipment	320.01	424.21	452.39	6.51	458.90
Total, Research and Development	5,989.74	6,116.66	6,160.22	369.48	6,529.70
Conduct of Education and Training	780.09	734.30	744.15	30.52	774.67
Non-Investment Activities	628.14	612.53	659.65	-	659.65
TOTAL	$7,397.97	$7,463.49	$7,564.02	$400.00	$7,964.02

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

RESEARCH AND RELATED ACTIVITIES

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	$4,844.51	$4,800.92	$4,796.81	$300.75	$5,097.56
Applied Research	439.82	461.53	471.02	32.22	503.24
Subtotal, Conduct of R&D	5,284.33	5,262.45	5,267.83	332.97	5,600.80
Physical Assets					
Research and Development Facilities	7.61	7.53	7.53	0.45	7.98
Research and Development Major Equipment	167.63	216.37	251.74	6.06	257.80
Subtotal, R&D Facilities & Major Equipment	175.24	223.90	259.27	6.51	265.78
Total, Research and Development	5,459.57	5,486.35	5,527.10	339.48	5,866.58
Conduct of Education and Training	317.18	314.30	314.15	6.53	320.68
Non-Investment Activities	264.82	233.00	238.18	-	238.18
TOTAL	$6,041.57	$6,033.65	$6,079.43	$346.01	$6,425.44

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

EDUCATION AND HUMAN RESOURCES

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	$129.39	$140.00	$150.00	$10.00	$160.00
Applied Research	256.01	290.00	290.00	20.00	310.00
Subtotal, Conduct of R&D	385.40	430.00	440.00	30.00	470.00
Physical Assets					
Research and Development Facilities	-	-	-	-	-
Research and Development Major Equipment	0.01	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	0.01	-	-	-	-
Total, Research and Development	385.41	430.00	440.00	30.00	470.00
Conduct of Education and Training	462.91	420.00	430.00	23.99	453.99
Non-Investment Activities	38.01	30.00	28.87	-	28.87
TOTAL	$886.33	$880.00	$898.87	$53.99	$952.86

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	-	-	-	-	-
Applied Research	-	-	-	-	-
Subtotal, Conduct of R&D	-	-	-	-	-
Physical Assets					
Research and Development Facilities	$144.76	$200.31	$193.12	-	$193.12
Research and Development Major Equipment	-	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	144.76	200.31	193.12	-	193.12
Total, Research and Development	144.76	200.31	193.12	-	193.12
Conduct of Education and Training	-	-	-	-	-
Non-Investment Activities	-	-	-	-	-
TOTAL	$144.76	$200.31	$193.12	-	$193.12

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

AGENCY OPERATIONS AND AWARD MANAGEMENT

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	-	-	-	-	-
Applied Research	-	-	-	-	-
Subtotal, Conduct of R&D	-	-	-	-	-
Physical Assets					
Research and Development Facilities	-	-	-	-	-
Research and Development Major Equipment	-	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	-	-	-	-	-
Total, Research and Development	-	-	-	-	-
Conduct of Education and Training	-	-	-	-	-
Non-Investment Activities	$306.56	$330.00	$373.02	-	$373.02
TOTAL	$306.56	$330.00	$373.02	-	$373.02

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

OFFICE OF INSPECTOR GENERAL

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	-	-	-	-	-
Applied Research	-	-	-	-	-
Subtotal, Conduct of R&D	-	-	-	-	-
Physical Assets					
Research and Development Facilities	-	-	-	-	-
Research and Development Major Equipment	-	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	-	-	-	-	-
Total, Research and Development	-	-	-	-	-
Conduct of Education and Training	-	-	-	-	-
Non-Investment Activities	$14.60	$15.16	$15.20	-	$15.20
TOTAL	$14.60	$15.16	$15.20	-	$15.20

Totals may not add due to rounding.

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE BOARD

Research and Development Special Analysis

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request (Discretionary)	FY 2017 Request (Mandatory)	FY 2017 Request Total
Investment Activities					
Conduct of Research and Development					
Basic Research	-	-	-	-	-
Applied Research	-	-	-	-	-
Subtotal, Conduct of R&D	-	-	-	-	-
Physical Assets					
Research and Development Facilities	-	-	-	-	-
Research and Development Major Equipment	-	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	-	-	-	-	-
Total, Research and Development	-	-	-	-	-
Conduct of Education and Training	-	-	-	-	-
Non-Investment Activities	$4.15	$4.37	$4.38	-	$4.38
TOTAL	$4.15	$4.37	$4.38	-	$4.38

Totals may not add due to rounding.