NATIONAL SCIENCE FOUNDATION

FY 2018 Budget Request to Congress

May 23, 2017

About the Cover:
Science has revolutionized the way we live our lives. As the only federal agency specifically mandated to support fundamental research across all fields of science, technology, engineering, and mathematics, NSF has supported discoveries and innovations that have transformed the way we live, sparked and expanded the limits of our curiosity, opened the world to entirely new occupations and industries, and enriched our quality of life. NSF plays a vital role in keeping the United States at the forefront of discovery and innovation.

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NOTES

Numbers in the tables and figures may not add up to totals because of rounding.

Amounts for FY 2017 were not available at the time this Budget Request was published.

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NSF FY 2018 Budget Request to Congress

*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.**"*

The President's FY 2018 Budget Request for the National Science Foundation (NSF) continues the Nation's longstanding commitment to support basic research and education across all fields of science and engineering. NSF funds basic research that pushes the boundaries of innovation and lays the groundwork for scientific breakthroughs that advance our Nation's economy, security, and global leadership. Also critical are NSF's education investments in science, technology, engineering, and mathematics (STEM) fields, which help to prepare future generations of scientists and engineers.

In January 2017, the President signed into law the American Innovation and Competitiveness Act (P.L. 114-329, abbreviated AICA), a bipartisan bill that affirms NSF's long-standing world renowned merit review process. AICA also addresses NSF's implementation of particular issues of importance such as increased transparency and accountability; management of multi-user facilities and mid-scale projects; and increased oversight of major research equipment and facilities. While maximizing research and education opportunities that help create the innovations that fuel our economy and create jobs, AICA also promotes the Foundation's commitment to diversity in STEM fields, incentivizes NSF's programs which encourage private-sector involvement, and re-affirms NSF's continued commitment to entrepreneurship and commercialization.

FY 2018 Budget Request

Total: $6.65 billion

Decrease: $840.98 million

-11.2% from FY 2016 Actuals

NSF's FY 2018 Budget Request is $6.653 billion, a decrease of $840.98 million (-11.2 percent) over the FY 2016 Actual investment. This funding will support approximately 8,000 new research grants, with an estimated funding rate of 19 percent for research grant proposals submitted to NSF. For comparison, in FY 2016, NSF funded 8,800 new research grants, with a funding rate of 21 percent.

The FY 2018 Budget Request reflects NSF's commitment to establishing clear priorities in areas of national importance, as well as to identifying innovative and promising research ideas, in order to yield return on investment for the Nation.

Federal investments in basic research and STEM workforce development are increasingly important to help establish U.S. leadership in next-generation technologies, especially as other nations intensify their support of research, development, and education. U.S. leadership is important, in part because of the unprecedented level of global competition for the highly skilled, technical workers who generate innovative scientific ideas.

As the only agency with a diverse portfolio that supports all fields of science and engineering, NSF helps to cultivate the Nation's role as a leader in the scientific enterprise by supporting the fundamental research that is so vital to the commercial marketplace and by building the workforce necessary to address the complex challenges that face the Nation.

NSF's Big Ideas

In 2016, NSF unveiled a set of "Big Ideas"—10 bold, long-term research ideas that identify areas for future investment at the frontiers of science and engineering. With its broad portfolio of investments, NSF is uniquely suited to advance this set of cutting-edge research agendas and processes that will require collaborations with industry, private foundations, other agencies, science academies and societies, and universities and the education sector. The Big Ideas represent unique opportunities to position our Nation at the cutting edge—indeed to define that cutting edge—of global science and engineering leadership and to invest in basic research that advances the United States' prosperity, security, health, and well-being.

NSF remains firmly committed to the Big Ideas, which are at different levels of readiness. The FY 2018 Budget Request to Congress details a variety of activities related to the Big Ideas that (1) continue the investment in developing the research foundations, including piloting select new programs; (2) build capacity in the research community, and (3) support the community-wide visioning and planning that will be crucial for effective implementation in the future. Together, these FY 2018 activities position NSF, and the Nation's research community, to move toward realizing the vision and potential of the Big Ideas.

Six of the Big Ideas are research ideas, which build on a foundation made possible by earlier investments in fundamental research.

- **Harnessing the Data Revolution—**Engaging NSF's research community in the pursuit of fundamental research in data science and engineering, the development of a cohesive, federated, national-scale approach to research data infrastructure, and the development of a 21st-century data-capable workforce.

- **Work at the Human Technology Frontier: Shaping the Future—**Understanding how constantly evolving technologies are actively shaping the lives of workers and how people in turn can shape those technologies, especially in the world of work.

- **Windows on the Universe: The Era of Multi-messenger Astrophysics—**Using powerful new syntheses of observational approaches to provide unique insights into the nature and behavior of matter and energy and help to answer some of the most profound questions before humankind.

- **The Quantum Leap: Leading the Next Quantum Revolution—**Exploiting quantum mechanics to observe, manipulate, and control the behavior of particles and energy at atomic and subatomic scales, resulting in next-generation technologies for sensing, computing, modeling, and communicating.

- **Understanding the Rules of Life: Predicting Phenotype—**Elucidating the sets of rules that predict an organism's observable characteristics, its phenotype.

- **Navigating the New Arctic—**Establishing an observing network of mobile and fixed platforms and tools across the Arctic to document and understand the Arctic's rapid biological, physical, chemical, and social changes.

Four of the Big Ideas are process ideas, which address NSF practices that could be altered or enhanced to capture the best research and to welcome new members to the science community.

- **Mid-scale Research Infrastructure—**Developing an agile process for funding experimental research capabilities in the mid-scale range.

- **NSF 2026: Seeding Innovation—**Investing in bold foundational research questions that are large in scope, innovative in character, originate outside of any particular directorate, and require a long-term commitment. This Big Idea is framed around the year 2026 in order to tie into the Nation's 250th anniversary ("sestercentennial").

- **NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science): Enhancing Science and Engineering through Diversity—**Transforming education and career pathways to help broaden participation in science and engineering.

- **Growing Convergent Research at NSF—**Framing challenging research questions at inception, and fostering the collaborations needed for successful inquiry.

FY 2018 NSF-Wide 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 2018, NSF continues to support seven continuing cross-Foundation investments.

FY 2018 Funding for Ongoing NSF-Wide Investments
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Cyber-Enabled Materials, Manufacturing	$271.52	-	$222.43	-$49.09	-18.1%
Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	13.97	-	14.88	0.91	6.5%
Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)	80.10	-	24.40	-55.70	-69.5%
NSF Innovation Corps (I-Corps™)	29.74	-	26.15	-3.59	-12.1%
Risk and Resilience	42.94	-	31.15	-11.79	-27.4%
Secure and Trustworthy Cyberspace (SaTC)	129.78	-	113.75	-16.03	-12.3%
Understanding the Brain (UtB)	172.75	-	134.46	-38.29	-22.2%

Several of these NSF-wide Investments are reduced over the FY 2016 Actual investment. NSF's commitment to these areas remains strong as the fundamental research programs across the agency will continue to invest in the basic research that advances these specific focus areas.

Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) ($222.43 million) aims to integrate science and engineering activities across NSF, including breakthrough materials, advanced manufacturing, and smart systems, which include robotics and cyber-physical systems. Research has led to discoveries of materials with unique properties and functionality that can be developed more reliably and efficiently via the integration of theory, modeling and simulation, data analytics, and experimentation. The integration of advanced materials with capabilities of intelligence is transforming static systems, processes, and edifices into adaptive, pervasive, and smart systems. These smart systems will be able to act independently and intelligently in dynamic, uncertain, and unanticipated environments. They will contribute to advanced manufacturing and have the potential to accelerate scientific and engineering discoveries to address key national and societal challenges critical to U.S. security and competitiveness. In FY 2018, CEMMSS will focus on increasing integration of the highest priority areas such as those related to materials and manufacturing, and developing smart systems.

Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) ($14.88 million) is an integrated, national initiative to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved or underrepresented in the science, technology, engineering, and mathematics (STEM) enterprise. Providing opportunities and support for members of all communities and sectors across the United States is necessary for the Nation's economic welfare and as part of NSF's commitment to equity. Investments aim to produce measurable, sustainable progress at the national level and to scale effective approaches to diversity and inclusion in STEM. NSF INCLUDES is one of NSF's 10 Big Ideas.

Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) ($24.40 million) 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. INFEWS, however, is the first program to study the interconnected food-energy-water nexus. This program is driven by pressing needs and challenges, such as growing U.S. and global populations, changes in land use, and increasing geographic and seasonal variability in precipitation patterns, all of which 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 Innovation Corps (I-Corps™) ($26.15 million) improves NSF-funded researchers' access to resources that can assist in bridging the gap between discoveries and technologies, helping to transfer knowledge to downstream technological applications and use at scale. In FY 2018, 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.

Risk and Resilience investments ($31.15 million) 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. In FY 2018, Prediction of and Resilience against Extreme Events (PREEVENTS) and the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program will continue, along with other contributing activities. PREEVENTS is a focused research effort that will help to better understand and mitigate the risks posed to the U.S. by natural hazards. The CRISP program will promote research on Interdependent Critical Infrastructures (ICI) systems and processes and educate the next generation of scientists and engineers in how to best improve the resilience of our infrastructures in the face of changing and increasing risks. The projects supported will make ICI services more effective, efficient, dependable, adaptable, resilient, safe, and secure.

The **Secure and Trustworthy Cyberspace (SaTC)** ($113.75 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.

Understanding the Brain (UtB) ($134.46 million) encompasses ongoing cognitive science and neuroscience research and NSF's contributions to the ongoing 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. 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 brain, behavior, and environment interact; and how the brain can recover from lost functionality.

Additional Highlights

- NSF fully funds the construction of three **major research equipment and facilities projects** ($182.80 million). Funding these projects is an essential part of the science and engineering enterprise that enables science to advance in ways that would not otherwise be possible. These three projects include the following: The Daniel K. Inouye Solar Telescope, which will be the world's most powerful ground-based solar telescope and will enable astronomers to gain new insights into solar phenomena; The Large Synoptic Survey Telescope, which will produce the deepest, widest image of the universe; Regional

Class Research Vessels, a major component in the plan for modernizing the U.S. Academic Research Fleet.

- NSF is responsible for the management of **polar facilities and logistics** ($284.96 million). Operational support in the Arctic and the Antarctic plays an indispensable role in allowing the international research community to carry on their work in these regions. The United States is a leading nation in polar science, and research results have global significance.

- Cutting-edge, NSF-supported research—as well as education and workforce development programs—are helping to assist in areas of national priority, such as **cybersecurity and advanced manufacturing** ($144.50 million and $173.33 million, respectively). NSF investments in these areas have helped to develop innovative ways to secure information and ensure privacy on the Internet, as well as to improve the manufacturing sector's improve its efficiency, competitiveness, and sustainability.

- The **National Strategic Computing Initiative (NSCI)** was established to advance national leadership in High-Performance Computing (HPC) and maximize the benefits of HPC for scientific discovery and economic competitiveness. Under NSCI, NSF will support research advances in new computing technologies, architectures, and platforms for the future, as well as the development and deployment of advanced HPC systems, including maximizing their benefits through deep integration of HPC cyberinfrastructure with science and engineering research. NSF is one of three lead agencies for NSCI, with the Department of Defense and the Department of Energy.

- In FY 2018, NSF will continue investments to extend the frontiers of **high-performance computing** ($60.0 million). This investment will support the acquisition and deployment of a new HPC system that will serve as a national resource for providing predictable and sustained long-term capabilities for science and engineering to push the frontiers of knowledge and ultimately promote the health, prosperity, and welfare of the Nation.

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. NSF's investments for FY 2018 focus on the following priorities:

- The **CyberCorps®: Scholarship for Service (SfS)** program ($40.0 million, a decrease of $9.98 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 U.S. higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure. FY 2018 activities will include engaging first- and second-year undergraduate students, especially veterans.

- **Computer Science for All (CSforAll)** ($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. CSforAll aims to provide high school teachers with the preparation, professional development, and ongoing support that they need to teach rigorous computer science courses and to give preK-8 teachers the instructional materials and preparation they need to integrate computer science and computation thinking into their teaching.

- The **Improving Undergraduate STEM Education (IUSE)** ($96.50 million, a decrease of $8.27 million) initiative supports the development of the STEM and STEM-capable workforce by investing in the improvement of undergraduate STEM education, with a focus on attracting and retaining students and on degree completion. In FY 2018, $15.0 million is included for IUSE: Hispanic Serving Institutions (HSI). The primary goals of the IUSE: HSI activity are to promote research on engaged student learning and development of effective STEM learning opportunities at HSIs, especially those that have not had substantial NSF funding, to incentivize institutional and community transformation, and to promote fundamental research about what it takes to diversify and increase participation in STEM effectively, including research that improves the understanding of how to build institutional capacity at HSIs.

- Through the **Advanced Technological Education (ATE)** ($59.0 million, a decrease of $7.04 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 Program (GRFP)** ($246.54 million, a decrease of $85.80 million) 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. In FY 2018, NSF will support 1,000 new fellows, equal to the number supported in FY 2008, a reduction from the 2,000 new fellows NSF has supported annually since 2011.

- **The NSF Research Traineeship (NRT)** ($40.10 million, a decrease of $15.88 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 2018, NSF requests funding to continue construction on three projects: the Daniel K. Inouye Solar Telescope (DKIST), Large Synoptic Survey Telescope (LSST), and Regional Class Research Vessels (RCRV).

- The **Daniel K. Inouye Solar Telescope** (DKIST) ($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 2018 is year 10 of an 11-year construction process. In FY 2018, installation of the telescope mount assembly (TMA) will be completed, and commission and acceptance testing of the TMA will be under way. By the end of FY 2018, the installation of the M1 main mirror will be under way and the alignment of the mirror with the laser metrology system will have begun. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered to the site, assembled, and will begin initial checkout.

- The **Large Synoptic Survey Telescope** (LSST) ($57.80 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 2018 is year five of a nine year construction process.

- The **Regional Class Research Vessel** (RCRV) ($105.0 million) project will help satisfy the anticipated ocean science requirements for the U.S. East Coast, West Coast, and Gulf of Mexico through the construction of three new research vessels. This project is a major component in the plan for modernizing the U.S. Academic Research Fleet (ARF).[1] RCRVs are important to the national interest in terms of increasing understanding on many subjects including: the potential impacts of geohazards, such as storm surges and tsunamis; transportation and recreational use; natural resource identification and extraction; and fisheries and aquaculture. These vessels will also support the maintenance of coastal observing systems, such as those of the Ocean Observatory Initiative and many other moorings and platforms. This project will help ensure U.S. researchers have access to the sophisticated ships required to meet scientific demands in the coming decades.

[1] National Ocean Council. (2013). *Federal oceanographic fleet status report.*
Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

Organizational Excellence

NSF seeks to integrate mission, vision, and core values to efficiently and effectively execute NSF's 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. The portfolio of activities included in Organizational Excellence addresses the agency's operations and administrative functions, which underpin NSF's programmatic activities.

Staffing
In FY 2018, NSF will work towards full utilization of its established allocations of 1,443 FTE for federal staff and 199 FTE for staff hired under the Intergovernmental Personnel Act (IPAs). The Foundation recognizes that maintaining staffing levels is vital to effectively and efficiently achieving its mission.

FY 2018 Priorities
In FY 2018, the primary driver of the decrease for the Agency Operations and Award Management (AOAM) account is the completion of the headquarters relocation to Alexandria, Virginia. Accompanying this is a reduction in the annual rent and utilities for the new headquarters building.

- Underlying the FY 2018 Request is NSF's ongoing commitment to increase agency efficiency while constraining administrative costs.

- This is consistent with the Administration's commitment to manage programs and deliver critical services more effectively, to devote a greater percentage of taxpayer dollars to mission achievement, and to be more effective and efficient in supporting program outcomes—all while improving performance, maintaining staffing levels, and providing for the 1.9 percent cost-of-living adjustment.

- AOAM will continue to support operational activities to ensure the Foundation has sufficient resources to fund ongoing operational requirements and maintain essential services.

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 2018 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 2018, NSF has set six performance goals so that NSF can strategically monitor and oversee progress being made toward its larger aims. NSF also assesses progress through an annual process of strategic reviews of the objectives in its Strategic Plan.

In FY 2018, NSF will monitor the following annual goals:

- **Ensure that Key Program Investments Are on Track:** Ensure that key FY 2018 NSF-wide program investments are implemented and on track.

- **Ensure that Infrastructure Investments Are on Track:** Ensure program integrity and responsible stewardship of major research facilities and infrastructure.

- **Use Evidence to Guide Management Decisions:** Use evidence-based reviews to guide management investments.

- **Make Timely Award Decisions:** Inform applicants whether their proposals have been declined or recommended for funding in a timely manner.

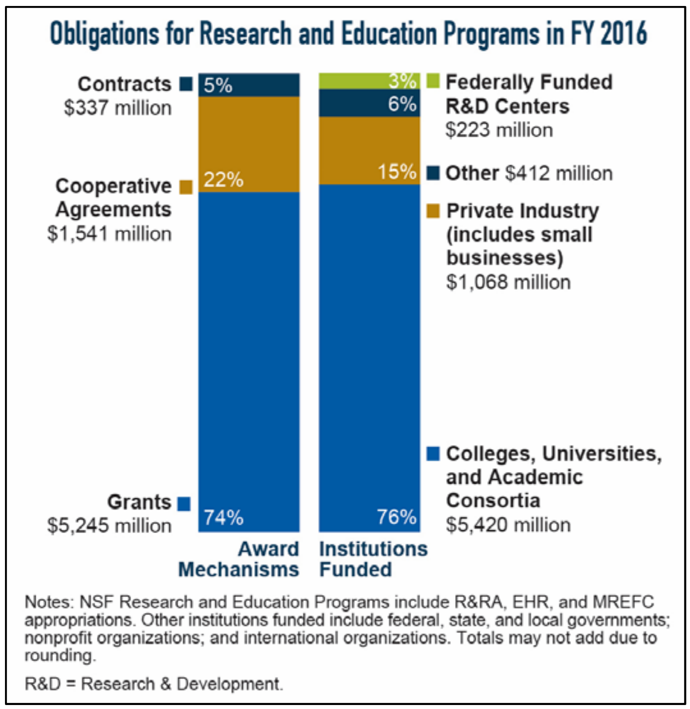
- **Improve Review Quality:** Improve the quality and usefulness to proposers of written reviews of NSF proposals.

- **Foster a Culture of Inclusion:** Foster a culture of inclusion through management efforts resulting in leadership that is committed, knowledgeable, and accountable.

NSF by the Numbers

NSF by the Numbers: In FY 2018, NSF expects to evaluate approximately 50,500 proposals through a competitive merit review process and make approximately 10,800 new competitive awards, which includes 8,000 new research grants. The number of new research grants decreases by roughly 11 percent from previous levels, in keeping with the overall change in total NSF funding. This process typically involves approximately 225,000 proposal reviews, engaging on the order of 34,000 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 2018, NSF support is expected to reach approximately 292,000 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 2016, the relative shares should provide a good indication of the distribution in FY 2018. As shown on the graph, 96 percent of NSF's FY 2016 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.



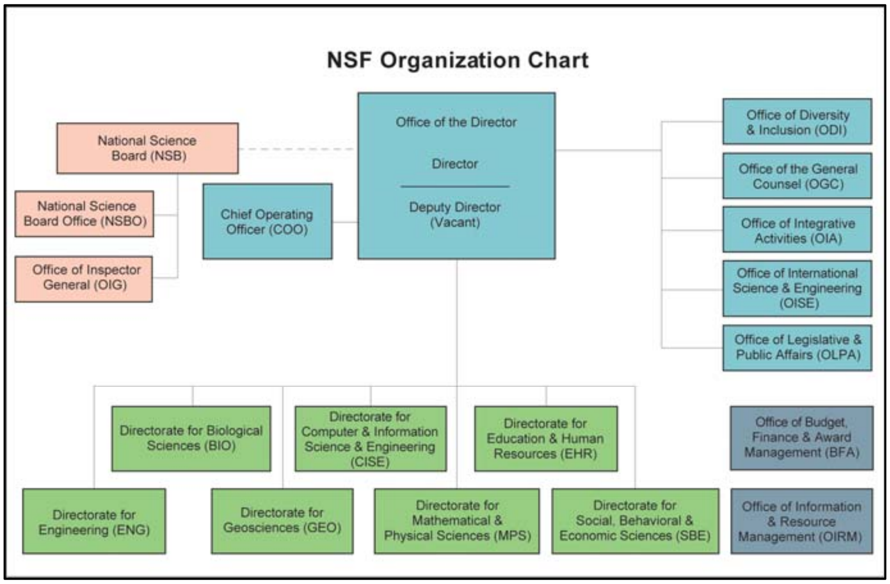
Most NSF awards are to academic institutions. As shown in the chart, 76 percent of support for research and education programs ($5,420 million) was to colleges (including two-year and community colleges), universities, and academic consortia. Private industry, including small businesses, accounted for 15 percent ($1,068 million), and support to federally funded research and development centers (FFRDCs) accounted for 3 percent ($223 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.

NSF Research Grant Awards and Funding Rate		
	FY 2016	FY 2018
Research Grant Awards	8,800	8,000
Funding Rate	21%	19%

The funding profile, shown on the left, presents a high-level, agency-wide estimate of funding rates, or proposal "success." This indicator is useful in gauging the relative impact of different funding levels. In FY 2018, the number of new research grant awards is expected to decrease by 800 compared to FY 2016. As noted above, the reduction is in keeping with the overall change in total NSF funding. This leads to a decline in the funding rate.

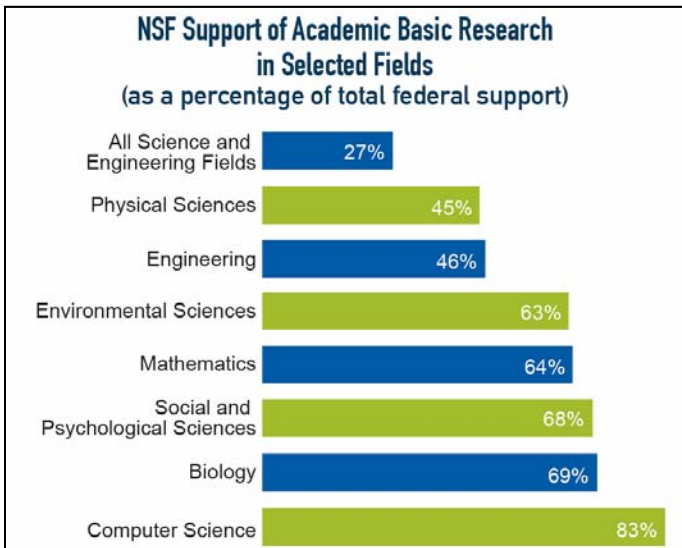
Organization and Role in the Federal Research Enterprise

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 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 27 percent of the total federal budget for basic research conducted at U.S. colleges and universities, and this share increases to approximately 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.



Notes: Biology includes Biological Sciences and Environmental Biology. Biology and Psychological Sciences exclude National Institutes of Health funding from the total amount of federal support.

Source: NSF/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FY 2015.

Highlights

For nearly 70 years, NSF has invested 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 only some of the important advances that NSF funding enables.

Eteri Svanidze (left) and Emilia Morosan developed a material that could make artificial joints more durable.
Credit: Jeff Fitlow/Rice University

Making Artificial Joints Stronger
Generally, titanium is the material of choice for artificial knees and hips. It is nontoxic, strong, and wears well. However, NSF-funded researchers at Rice University have discovered that adding gold to the metal can make it nearly four times harder than most steels. The new alloy is more compatible with the human body than titanium alone and outperforms it in wear and tear tests. Easy to synthesize, the new material may help reduce the 200,000 surgeries performed each year in the U.S. to replace failed hip and knee implants. This would be an important advance since knee replacements are expected to increase 673 percent and hip replacements by 174 percent by 2030.

Reimagining the Future of Farming
Much of the commercial fertilizer used today goes straight into groundwater. This includes nitrogen, one of fertilizer's main components and an environmental pollutant. NSF-funded researchers are using cutting-edge genomic tools to develop new plant varieties that use nitrogen more efficiently and don't require as much nitrogen to grow. By analyzing the DNA of specific plants, the researchers are working to identify which genes control nitrogen uptake. With approximately 30,000 plant genes to test, this "big data" job uses computers that are able to process large amounts of data quickly. Scientists have identified the gene networks that process nitrogen for use in plant growth and development. Researchers are exploring ways to help farmers get the same crop yield using less nitrogen by modifying the plants' genes. This research holds promise for reducing environmental pollution while also creating greater food security by improving crop yields in parts of the world with nitrogen-poor soil.


Computer science and biology intersect to process plant genomes.
Credit: Nicolle Rager Fuller, National Science Foundation

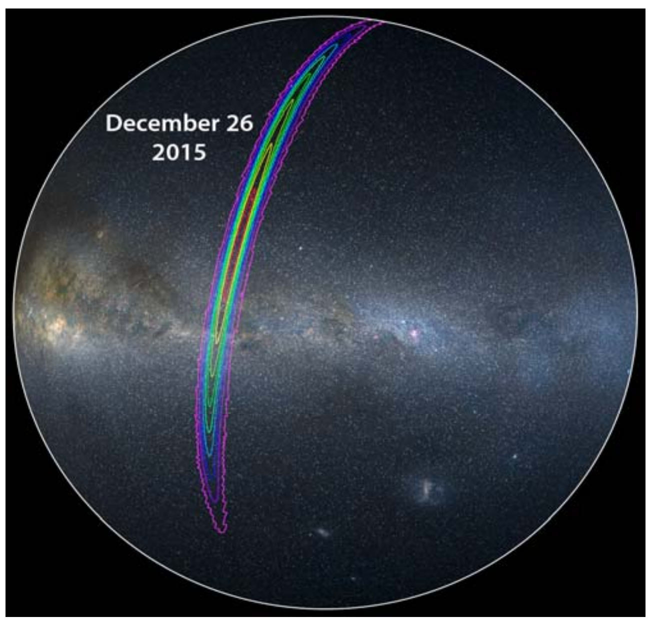
The NSF/NCAR Gulfstream V readies for takeoff on a mission to study a tropical storm. *Credit: Carlye Calvin/UCAR*

High Flyer Targets Hurricanes

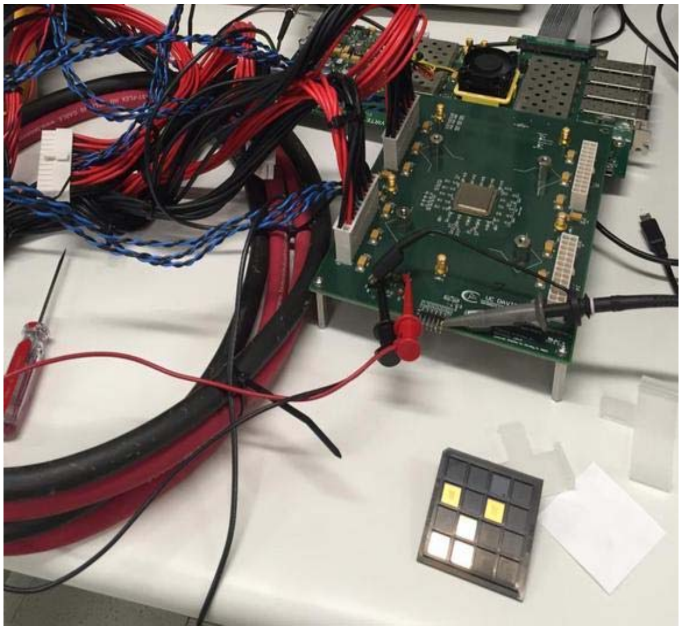
An NSF research aircraft helped improve storm forecasting during the 2016 hurricane season. Flying at altitudes up to 51,000 feet, the plane deploys parachute-borne sensors, known as GPS dropsondes. This NSF-funded technology pinpoints the location of conditions within the storm such as temperature and wind speed. Such observations improve hurricane tracking in the U.S. global weather model by about 15 percent during the 24 to 48 hours before landfall. According to the National Hurricane Center, warnings issued in that window have saved about 200 lives annually. The plane's surveillance missions during hurricane season are a partnership between NSF and the National Oceanic and Atmospheric Administration.

Wave hunting with LIGO

In December 2015, almost three months after the initial confirmation of the existence of gravitational waves in the universe, the NSF-funded Laser Interferometer Gravitational-Wave Observatory (LIGO) captured a second set of waves from another black hole merger 1.4 billion light years away. For the first time, researchers confirmed that one of the black holes was spinning, indicating that the spinning black hole experienced some dynamic process before the merger. Data from this observation allowed researchers to verify the validity of Einstein's theory of relativity, with more precision. NSF was the initial funder of gravitational wave projects 40 years ago and its continued commitment to LIGO's research now enables an entirely new way to observe the universe.



A computer simulates the massive black hole collisions that jettison gravitational waves so strong that NSF's LIGO can detect them billions of light years away. *Credit: LIGO/Axel Mellinger*



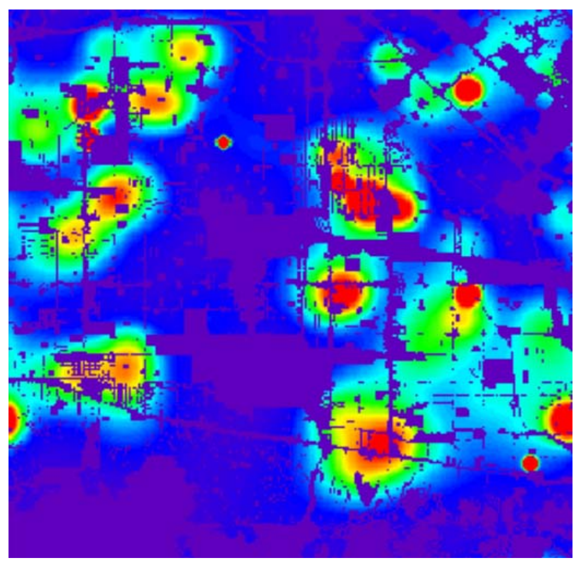
The Kilocore computer chip contains 1,000 independently programmable processors. *Credit: University of California, Davis*

Record-Breaking Computer Chip

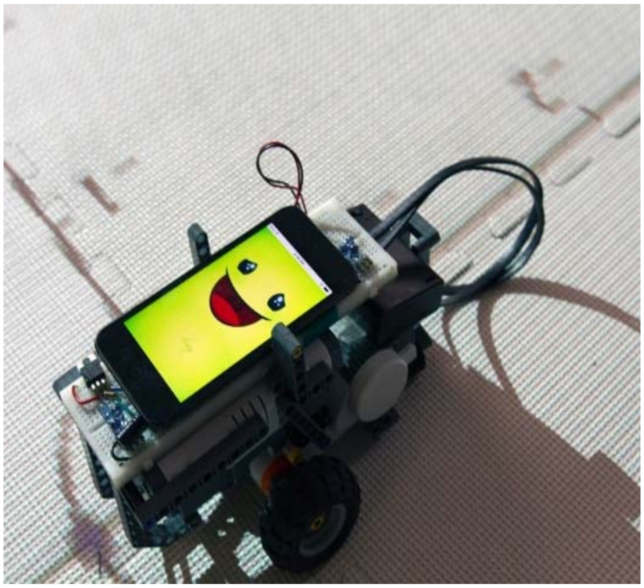
NSF-funded researchers from the University of California, Davis offered a glimpse of the future of data crunching and speedy data delivery in June 2016 when they unveiled their mega-fast 1,000 processor computer chip. The "Kilocore," considered the world's first such chip, has the highest processor rate (115 billion instructions per second) ever designed in an academic setting. As an added bonus, the chip, fabricated by IBM, is highly efficient, requiring only 0.7 watts of power from a single AA battery. That's 100 times more energy efficient than today's laptops. The Kilocore would speed up wireless coding, video processing and other applications involving large amounts of parallel data. Previously, multiple processor chips maxed out at about 300 processors according to the researchers.

Predicting Crime, Preventing Crime

An NSF-funded anthropologist at the University of California, Los Angeles designed a mathematical model to help predict where crime would likely occur. The model incorporated historical crime data, bus routes, business locations, and even weather. It provided police with a series of "prediction boxes," each 500 feet by 500 feet, where they should focus law enforcement efforts. Using the prediction boxes, the Los Angeles police effectively reduced crime in certain patrol areas compared to other patrol areas where standard methods were used. The models predicted twice as much crime as trained analysts using existing skills and technology. Today, more than 50 police departments around the country and world use the predictive policing platform to keep communities safe.



Two-dimensional discrete simulation of burglary hotspots in an 18 x 18 km area of the San Fernando Valley, Los Angeles. *Credit: UC Mathematical and Simulation Modeling of Crime Project*



The mighty Quinn rolls across mat, helping students to engage more fully in geometry. *Credit: Pete Zrioka, NYU*

Computer Science Moves Away from the Desk

Computers are now an indispensable tool in the classroom, but for young students the experience can be isolating. To move away from the traditional monitor, keyboard and mouse, a group of NSF-funded researchers, led by researchers at New York University, use a LEGO robot named Quinn to teach basic geometry concepts to middle school students. Quinn is the centerpiece of the Robo-Tangible Activities for Geometry (rTAG) system that encourages physical interactions with a robot. Using an iPod Touch, students "help" Quinn learn how to solve geometry problems as they guide the robot around a large, white floor mat.

Foldable Robots for the Clinic

NSF-funded researchers at the Massachusetts Institute of Technology have developed a tiny foldable robot the size of a small pill. This gives doctors an alternative to surgery to retrieve the some 3,500 button batteries that are swallowed annually in the United States. If left in the body, ingested batteries can burn the digestive tract. Once swallowed, the robot unfolds and moves toward its target via external magnetic field. Then it will dislodge the battery from the stomach lining, allowing both the battery and robot to be naturally passed from the digestive system. Besides foreign object retrieval, the devices can patch wounds and deliver medicine. After completing their mission, the robots are passed through the body or dissolve. The researchers plan to redesign the robot adding sensors so that it can control itself rather than relying on external manipulation.

NSF-funded researchers have developed an origami robot that folds into an ingestible capsule. *Credit: Melanie Gonick, MIT*

SUMMARY TABLES

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NATIONAL SCIENCE FOUNDATION
SUMMARY TABLE
FY 2018 Budget Request to Congress
(Dollars in Millions)

NSF by Account	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actuals Amount	Percent
BIO	$723.78	-	$672.11	-$51.67	-7.1%
CISE	935.20	-	838.92	-96.28	-10.3%
ENG	915.68	-	833.49	-82.19	-9.0%
Eng Programs	*727.16*	-	*657.28*	*-69.88*	*-9.6%*
SBIR/STTR	*188.52*	-	*176.21*	*-12.31*	*-6.5%*
GEO	876.51	-	783.31	-93.20	-10.6%
MPS	1,348.78	-	1,219.43	-129.35	-9.6%
SBE	272.20	-	244.02	-28.18	-10.4%
OISE	49.07	-	44.02	-5.05	-10.3%
OPP	448.87	-	409.18	-39.69	-8.8%
IA	426.57	-	315.74	-110.83	-26.0%
U.S. Arctic Research Commission	1.43	-	1.43	-	-
Research & Related Activities	**$5,998.09**	**$6,022.18**	**$5,361.65**	**-$636.44**	**-10.6%**
Education & Human Resources	**$884.10**	**$878.33**	**$760.55**	**-$123.55**	**-14.0%**
Major Research Equipment & Facilities Construction	**$241.50**	**$199.93**	**$182.80**	**-$58.70**	**-24.3%**
Agency Operations & Award Management	**$351.11**	**$329.37**	**$328.51**	**-$22.60**	**-6.4%**
National Science Board	**$4.31**	**$4.36**	**$4.37**	**$0.06**	**1.5%**
Office of Inspector General	**$14.76**	**$15.13**	**$15.01**	**$0.25**	**1.7%**
Total, NSF	**$7,493.86**	**$7,449.30**	**$6,652.89**	**-$840.98**	**-11.2%**

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 <u>Number of Proposals</u> 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 <u>Number of Awards</u> is also based on several factors, including estimated funding and expected proposal pool. The <u>Funding Rate</u> 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. <u>Annualized Award Size</u> 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. <u>Average Duration</u> is the length of awards in years.

NSF Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Request Estimate
Statistics for Competitive Awards			
Number of Proposals	49,200	-	50,500
Number of Awards	11,900	-	10,800
Funding Rate	24%	-	21%
Statistics for Research Grant Awards			
Number of Research Grant Proposals	41,100	-	42,100
Number of Research Grant Awards	8,800	-	8,000
Funding Rate	21%	-	19%
Median Annualized Award Size	$141,400	-	$141,000
Average Annualized Award Size	$178,600	-	$177,700
Average Duration (years)	2.9	-	2.90

NUMBER OF PEOPLE INVOLVED IN NSF ACTIVITIES

NSF estimates that in FY 2018 approximately 294,030 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 2018 Request
Number of People Involved in NSF Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	43,852	-	40,600
Other Professionals	14,127	-	12,850
Postdoctoral Associates	5,677	-	5,130
Graduate Students	40,884	-	37,950
Undergraduate Students	38,448	-	33,500
K-12 Teachers	44,123	-	34,500
K-12 Students	174,810	-	129,500
Total Number of People	**361,921**	**-**	**294,030**

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

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

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 2018

(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	5,801.63	880.29	845.44	210.12	200.00	304.29	306.26	14.32	14.28	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	5,989.68	962.57	878.97	200.31	218.31	354.84	357.00	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	*346.01*	-	*53.99*	-	-	-	-	-	-	-		-	*400.00*	-
2017 Total	6,425.44	-	952.86	-	193.12	-	373.02	-	15.20	-	4.38	-	7,964.02	-
2018	5,361.65	-	760.55	-	182.80	-	328.51	-	15.01	-	4.37	-	6,652.89	-

Appropriations as shown are post-transfer.

[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.

NATIONAL SCIENCE FOUNDATION
SELECTED CROSSCUTTING PROGRAMS
FY 2018 Budget Request to Congress
(Dollars in Millions)

Selected Cross-Cutting Programs		FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
ADVANCE	Research & Related Activities	13.38	-	3.37	-10.01	-74.8%
	Education & Human Resources	1.48	-	1.53	0.05	3.4%
	Total, NSF	**$14.86**	**-**	**$4.90**	**-$9.96**	**-67.0%**
Faculty Early Career Development - CAREER	Research & Related Activities	280.65	-	242.20	-38.45	-13.7%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$280.65**	**-**	**$242.20**	**-$38.45**	**-13.7%**
Graduate Research Fellowship - GRF	Research & Related Activities	165.96	-	123.27	-42.69	-25.7%
	Education & Human Resources	166.38	-	123.27	-43.11	-25.9%
	Total, NSF	**$332.34**	**-**	**$246.54**	**-$85.80**	**-25.8%**
NSF Research Traineeships - NRT[1]	Research & Related Activities	24.95	-	7.05	-17.90	-71.7%
	Education & Human Resources	31.03	-	33.05	2.02	6.5%
	Total, NSF	**$55.98**	**-**	**$40.10**	**-$15.88**	**-28.4%**
Total, Graduate Fellowships & Traineeships	Research & Related Activities	190.91	-	130.32	-60.59	-31.7%
	Education & Human Resources	197.42	-	156.32	-41.10	-20.8%
	Total, NSF	**$388.32**	**-**	**$286.64**	**-$101.68**	**-26.2%**
Integrated NSF Support Promoting Interdisciplinary Research and Education - INSPIRE	Research & Related Activities	11.52	-	-	-11.52	-100.0%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$11.52**	**-**	**-**	**-$11.52**	**-100.0%**
Long-Term Ecological Research Sites - LTERs	Research & Related Activities	30.63	-	29.42	-1.20	-3.9%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$30.63**	**-**	**$29.42**	**-$1.20**	**-3.9%**
Research Experiences for Undergraduates - REU - Sites Only	Research & Related Activities	73.88	-	55.06	-18.82	-25.5%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$73.88**	**-**	**$55.06**	**-$18.82**	**-25.5%**
Research Experiences for Undergraduates - REU - Supplements Only	Research & Related Activities	23.84	-	19.65	-4.19	-17.6%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$23.84**	**-**	**$19.65**	**-$4.19**	**-17.6%**
Total, Research Experiences for Undergraduates - REU	Research & Related Activities	97.72	-	74.71	-23.01	-23.5%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$97.72**	**-**	**$74.71**	**-$23.01**	**-23.5%**
Research in Disabilities Education - RDE	Research & Related Activities	1.47	-	-	-1.47	-100.0%
	Education & Human Resources	7.82	-	5.50	-2.32	-29.7%
	Total, NSF	**$9.29**	**-**	**$5.50**	**-$3.79**	**-40.8%**
Research in Undergraduate Institutions - RUI	Research & Related Activities	43.54	-	35.34	-8.20	-18.8%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$43.54**	**-**	**$35.34**	**-$8.20**	**-18.8%**

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $5.91 million in FY 2016. There is no IGERT funding beyond FY 2016.

NATIONAL SCIENCE FOUNDATION
NSTC CROSSCUTS SUMMARY
FY 2018 Request to Congress

(Dollars in Millions)

	National Nanotechnology Initiative (NNI)				
	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
BIO	$48.80	-	$42.50	-$6.30	-12.9%
CISE	13.55	-	12.10	-1.45	-10.7%
ENG	207.50	-	168.50	-39.00	-18.8%
GEO	0.30	-	-	-0.30	-100.0%
MPS	237.10	-	162.53	-74.57	-31.5%
SBE	0.53	-	0.40	-0.13	-24.5%
OISE	0.10	-	0.10	-	-
R&RA	**$507.88**	**-**	**$386.13**	**-$121.75**	**-24.0%**
EHR	**$2.50**	**-**	**$2.50**	**-**	**-**
NSF Total	**$510.38**	**-**	**$388.63**	**-$121.75**	**-23.9%**

	Networking & Information Technology R&D (NITRD)				
	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
BIO	$99.00	-	$69.00	-$30.00	-30.3%
CISE	933.76	-	838.92	-94.84	-10.2%
ENG	29.50	-	23.25	-6.25	-21.2%
GEO	24.00	-	22.00	-2.00	-8.3%
MPS	94.75	-	76.50	-18.25	-19.3%
SBE	28.14	-	22.71	-5.43	-19.3%
R&RA	**$1,209.15**	**-**	**$1,052.38**	**-$156.77**	**-13.0%**
EHR	**$9.50**	**-**	**$9.50**	**-**	**-**
NSF Total	**$1,218.65**	**-**	**$1,061.88**	**-$156.77**	**-12.9%**

	U.S. Global Change Research Program (USGCRP)				
	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
BIO	$103.63	-	$94.00	-$9.63	-9.3%
GEO	185.94	-	140.00	-45.94	-24.7%
MPS	8.00	-	-	-8.00	-100.0%
SBE	17.98	-	14.98	-3.00	-16.7%
OPP	15.15	-	15.15	-	-
R&RA	**$330.70**	**-**	**$264.13**	**-$66.57**	**-20.1%**
EHR	**-**	**-**	**-**	**-**	**N/A**
NSF Total	**$330.70**	**-**	**$264.13**	**-$66.57**	**-20.1%**

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NATIONAL SCIENCE FOUNDATION
PROGRAMS TO BROADEN PARTICIPATION
FY 2018 Request to Congress
(Dollars in Millions)

Group/Program	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
Total, NSF Broadening Participation Programs	**$975.09**	**-**	**$752.38**	**-$222.71**	**-22.8%**

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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	FY 2018 Request Change Over FY 2016 Actual: Percent
ADVANCE	100%	$14.86	-	$4.90	-$9.96	-67.0%
Alliances for Graduate Education & the Professoriate (AGEP)	100%	8.00	-	7.00	-1.00	-12.5%
AGEP Graduate Research Supplements (AGEP-GRS)	100%	1.99	-	2.84	0.85	42.7%
Broadening Participation in Biology Fellowships	100%	3.45	-	2.50	-0.95	-27.5%
Broadening Participation in Engineering (BPE)	100%	10.00	-	7.00	-3.00	-30.0%
Career-Life Balance (CLB)	100%	0.55	-	0.47	-0.08	-14.5%
Centers of Research Excellence in Science & Technology (CREST)	100%	24.04	-	24.00	-0.04	-0.2%
Excellence Awards in Science & Engineering (EASE)[1]	100%	5.59	-	3.82	-1.77	-31.7%
Historically Black Colleges & Universities Undergraduate Program (HBCU-UP)	100%	35.01	-	35.00	-0.01	-0.0%
Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	100%	13.97	-	14.88	0.91	6.5%
Louis Stokes Alliances for Minority Participation (LSAMP)	100%	46.01	-	40.67	-5.34	-11.6%
Partnerships for Research & Education in Materials (PREM)	100%	6.38	-	6.30	-0.08	-1.3%
Partnerships in Astronomy & Astrophysics Research Education (PAARE)	100%	1.50	-	1.00	-0.50	-33.3%
SBE Postdoctoral Research Fellowships-Broadening Participation	100%	1.32	-	1.50	0.18	13.9%
SBE Science of Broadening Participation	100%	1.50	-	1.50	-	-
Tribal Colleges & Universities Program (TCUP)	100%	14.01	-	13.00	-1.01	-7.2%
Subtotal, Focused Programs		**$188.17**	**-**	**$166.38**	**-$21.79**	**-11.6%**

[1] 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual	
					Amount	Percent
Advancing Informal STEM Learning (AISL)	53%	$33.12	-	$33.13	$0.00	0.0%
Disability and Rehabilitation Engineering (DARE)[1]	55%	2.67	-	2.20	-0.47	-17.7%
Discovery Research PreK-12 (DR-K12)	62%	52.26	-	51.30	-0.97	-1.8%
Engineering Research Centers (ERC)	63%	35.53	-	36.23	0.70	2.0%
Graduate Research Fellowship (GRF)	63%	209.38	-	155.32	-54.06	-25.8%
Improving Undergraduate STEM Education (IUSE)	56%	58.67	-	54.04	-4.63	-7.9%
Innovative Technology Experiences for Students and Teachers (ITEST)[2]	51%	22.62	-	12.75	-9.87	-43.6%
International Research Experiences for Students (IRES)	53%	3.14	-	5.93	2.78	88.6%
Robert Noyce Teacher Scholarship Program (NOYCE)	61%	39.34	-	32.87	-6.47	-16.4%
NSF Scholarships in STEM (S-STEM)[2]	59%	82.92	-	44.25	-38.67	-46.6%
Research Experiences for Undergraduates (REU) - Sites and Supplements	55%	53.75	-	41.09	-12.66	-23.5%
STEM + Computing Partnerships (STEM+C Partnerships)	52%	33.47	-	16.90	-16.57	-49.5%
Subtotal, Emphasis Programs		**$626.88**	**-**	**$486.00**	**-$140.89**	**-22.5%**

[1] Program formally known as General and Age Related Disabilities Engineering (GARDE).

[2] Amounts for Innovative Technology Experiences for Students and Teachers (ITEST) and 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	FY 2018 Request Change Over FY 2016 Actual: Percent
EPSCoR	100%	$160.03	-	$100.00	-$60.03	-37.5%
Subtotal, Geographic Diversity Program		**$160.03**	**-**	**$100.00**	**-$60.03**	**-37.5%**

NATIONAL SCIENCE FOUNDATION
COSTEM INVENTORY AND POSTDOCTORAL FELLOWSHIP PROGRAMS
By Level of Education
FY 2018 Request to Congress
(Dollars in Millions)

		FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
Minority-Serving Institutions		**$49.02**	**-**	**$48.00**	**-1.02**	**-2.1%**
UG	Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	35.01	-	35.00	-0.01	-0.0%
UG	Tribal Colleges and Universities Program (TCUP)	14.01	-	13.00	-1.01	-7.2%
Fellowships and Scholarships		**$644.72**	**-**	**$455.53**	**-$189.19**	**-29.3%**
UG	NSF Scholarships in STEM (S-STEM) (H-1B)	140.54	-	75.00	-65.54	-46.6%
UG	Robert Noyce Scholarship (Noyce) Program	64.50	-	53.89	-10.61	-16.4%
G	Cybercorps®: Scholarship for Service (SFS)	49.98	-	40.00	-9.98	-20.0%
G	East Asia and Pacific Summer Institutes for U.S. Grad Students (EAPSI)[1]	1.38	-	-	-1.38	-100.0%
G	Graduate Research Fellowship (GRF)	332.34	-	246.54	-85.80	-25.8%
G	NSF Research Traineeship (NRT)[2]	55.98	-	40.10	-15.88	-28.4%
Other Grant Programs		**$609.69**	**-**	**$516.55**	**-$93.14**	**-15.3%**
K-12	Discovery Research PreK-12 (DRK-12)	84.30	-	82.74	-1.56	-1.8%
K-12	Innovative Technology Experiences for Teachers and Students (ITEST) (H1-B)	44.35	-	25.00	-19.35	-43.6%
K-12	STEM + Computing (STEM + C) Partnerships	64.37	-	32.50	-31.87	-49.5%
UG	Advanced Technological Education (ATE)	66.04	-	59.00	-7.04	-10.7%
UG	Improving Undergraduate STEM Education (IUSE)	104.77	-	96.50	-8.27	-7.9%
UG	International Research Experiences for Students (IRES)	5.93	-	11.18	5.25	88.6%
UG	Louis Stokes Alliances for Minority Participation (LSAMP)	46.01	-	40.67	-5.34	-11.6%
UG	Research Experiences for Undergraduates (REU) - Sites and Supplements	97.72	-	74.71	-23.01	-23.5%
UG	Research Experiences for Teachers (RET) in Engineering and Computer Science	6.14	-	6.05	-0.09	-1.5%
G	Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.00	-1.00	-12.5%
O&I	Advancing Informal STEM Learning (AISL)	62.50	-	62.50	-	-
O&I	Excellence Awards in Science and Engineering (EASE)	5.59	-	3.82	-1.77	-31.7%
O&I	Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	13.97	-	14.88	0.91	6.5%
Subtotal, Above Categories (CoSTEM Inventory Programs)		**$1,303.43**	**-**	**$1,020.08**	**-$283.35**	**-21.7%**
G	**NSF Postdoctoral Programs**	**$27.18**	**-**	**$22.68**	**-$4.50**	**-16.6%**
	Astronomy and Astrophysics Postdoctoral Fellowships (AAPF)	2.31	-	2.50	0.19	8.0%
	Geosciences Postdoctoral Fellowships	3.47	-	3.38	-0.09	-2.6%
	International Research Fellowship Program	2.32	-	-	-2.32	-100.0%
	Mathematical Sciences Postdoctoral Research Fellowships (MSPRF)	6.00	-	6.00	-	-
	Postdoctoral Research Fellowships in Biology (PRFB)	9.65	-	7.80	-1.85	-19.2%
	SPRF-Broadening Participation	1.32	-	1.50	0.18	13.9%
	SPRF-Interdisciplinary Research in Behavioral and Social Sciences (SPRF-IBSS)[3]	2.11	-	-	-2.11	-100.0%
	SPRF-Fundamental Research[3]	-	-	1.50	1.50	N/A

National Science Foundation
CoSTEM Inventory and Postdoctoral Fellowship Programs
By Level of Education
FY 2018 Request to Congress
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual	
				Amount	Percent
K-12 STEM Education Programs (K-12) Subtotal	**$193.00**	**-**	**$140.24**	**-$52.76**	**-27.3%**
Undergraduate STEM Education Programs (UG) Subtotal	**$580.59**	**-**	**$465.00**	**-$115.59**	**-19.9%**
Graduate and Professional STEM Education Programs (G) Subtotal	**$474.86**	**-**	**$356.32**	**-$118.54**	**-25.0%**
Outreach and Informal STEM Education Programs (O&I) Subtotal	**$82.06**	**-**	**$81.20**	**-$0.86**	**-1.0%**
Total, NSF STEM Education	**$1,330.52**	**-**	**$1,042.76**	**-$287.76**	**-21.6%**

[1] In FY 2018, the East Asia-Pacific Summer Institute (EAPSI) program will be suspended to review the program and its outcomes.

[2] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and were $5.91 million in FY 2016. There is no IGERT funding beyond FY 2016.

[3] SPRF-IBSS was discontinued after FY 2016 and replaced with SPRF-Fundamental Research. SPRF-IBSS focused solely on interdisciplinary research proposals. SPRF-Fundamental Research supports all research within the Social, Behavioral, and Economic sciences in addition to interdisciplinary research.

NATIONAL SCIENCE FOUNDATION
EDUCATION AND HUMAN RESOURCES FUNDING BY DIVISION AND PROGRAM
FY 2018 Request to Congress
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual: Amount	Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	**$224.32**	**-**	**$199.57**	**-$24.75**	**-11.0%**
Learning and Learning Environments	**25.65**	**-**	**34.33**	**8.68**	**33.9%**
EHR Core Research (ECR): STEM Learning	25.65	-	34.33	8.68	33.9%
Broadening Participation and Institutional Capacity	**146.80**	**-**	**145.24**	**-1.56**	**-1.1%**
Advancing Informal STEM Learning (AISL)	62.50	-	62.50	-	-
Discovery Research PreK-12 (DRK-12)	84.30	-	82.74	-1.56	-1.8%
STEM Professional Workforce	**51.87**	**-**	**20.00**	**-31.87**	**-61.4%**
Science, Technology, Engineering, and Mathematics + Computing (STEM + C) Partnerships	51.87	-	20.00	-31.87	-61.4%
Division of Graduate Education (DGE)	**$278.19**	**-**	**$221.29**	**-$56.90**	**-20.5%**
Learning and Learning Environments	**14.57**	**-**	**9.00**	**-5.57**	**-38.2%**
Project and Program Evaluation (PPE)	14.57	-	9.00	-5.57	-38.2%
STEM Professional Workforce	**263.40**	**-**	**212.29**	**-51.11**	**-19.4%**
EHR Core Research (ECR): STEM Professional Workforce	16.00	-	15.97	-0.03	-0.2%
Cybercorps®: Scholarship for Service (SFS)	49.98	-	40.00	-9.98	-20.0%
Graduate Research Fellowship (GRF)	166.38	-	123.27	-43.11	-25.9%
NSF Research Traineeship (NRT)[1]	31.03	-	33.05	2.02	6.5%
Division of Human Resource Development (HRD)	**$149.31**	**-**	**$135.30**	**-$14.01**	**-9.4%**
Learning and Learning Environments	**58.49**	**-**	**56.53**	**-1.96**	**-3.4%**
ADVANCE	1.48	-	1.53	0.05	3.4%
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.00	-1.00	-12.5%
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	35.01	-	35.00	-0.01	-0.0%
Tribal Colleges and Universities Program (TCUP)	14.01	-	13.00	-1.01	-7.2%
Broadening Participation and Institutional Capacity	**61.19**	**-**	**50.95**	**-10.24**	**-16.7%**
EHR Core Research (ECR): Broadening Participation and Institutional Capacity in STEM	12.90	-	7.28	-5.62	-43.6%
NSF INCLUDES	2.28	-	3.00	0.72	31.9%
Louis Stokes Alliances for Minority Participation (LSAMP)	46.01	-	40.67	-5.34	-11.6%
STEM Professional Workforce	**29.63**	**-**	**27.82**	**-1.81**	**-6.1%**
Centers for Research Excellence in Science and Technology (CREST)	24.04	-	24.00	-0.04	-0.2%
Excellence Awards in Science and Engineering (EASE)	5.59	-	3.82	-1.77	-31.7%
Division of Undergraduate Education (DUE)	**$232.29**	**-**	**$204.39**	**-$27.90**	**-12.0%**
Learning and Learning Environments	**100.03**	-	**91.50**	**-8.53**	**-8.5%**
EHR Core Research (ECR): STEM Learning Environments	13.02	-	4.50	-8.52	-65.5%
Improving Undergraduate STEM Education (IUSE)	87.00	-	87.00	-	-
STEM Professional Workforce	**132.08**	**-**	**112.89**	**-19.19**	**-14.5%**
Advanced Technological Education (ATE)	66.04	-	59.00	-7.04	-10.7%
NSF Innovation Corps (I-Corps™)[2]	1.55	-	-	-1.55	-100.0%
Robert Noyce Teacher Scholarship Program (Noyce)	64.50	-	53.89	-10.61	-16.4%
Total, EHR	**$884.10**	**-**	**$760.55**	**-$123.55**	**-14.0%**
Total, Learning and Learning Environments	$198.74	-	$191.36	**-$7.38**	**-3.7%**
Total, Broadening Participation and Institutional Capacity	$207.98	-	$196.19	**-$11.79**	**-5.7%**
Total, STEM Professional Workforce	$476.98	-	$373.00	**-$103.98**	**-21.8%**

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and were $10,000 in FY 2016 for DGE. There is no IGERT funding beyond FY 2016.

[2] In FY 2018, NSF will invest $26.15 million on I-Corps™; EHR will not be contributing to the program.

NATIONAL SCIENCE FOUNDATION
RESEARCH INFRASTRUCTURE (RI) FUNDING BY ACCOUNT AND ACTIVITY
FY 2018 Request to Congress
(Dollars in Millions)

	FY 2016 Actual	FY 2016 Actual RI Funding	**FY 2017 (TBD)**	FY 2017 RI Funding (TBD)	**FY 2018 Request**	FY 2018 Request RI Funding	**FY 2018 Request RI Change Over FY 2016 Actual RI** Amount	Percent
BIO	**$723.78**	$131.52	-	-	**$672.11**	$140.54	$9.02	6.9%
CISE	**935.20**	169.20	-	-	**838.92**	158.10	-11.10	-6.6%
ENG	**915.68**	29.70	-	-	**833.49**	26.58	-3.12	-10.5%
GEO	**876.51**	388.73	-	-	**783.31**	329.22	-59.51	-15.3%
MPS	**1,348.78**	357.40	-	-	**1,219.43**	324.55	-32.85	-9.2%
SBE	**272.20**	62.61	-	-	**244.02**	56.53	-6.08	-9.7%
OISE	**49.07**	0.10	-	-	**44.02**	0.10	-	-
OPP	**448.87**	323.09	-	-	**409.18**	297.25	-25.84	-8.0%
IA	**426.57**	81.42	-	-	**315.74**	77.84	-3.58	-4.4%
U.S. Arctic Research Commission	**1.43**	-	-	-	**1.43**	-	-	N/A
Research & Related Activities	**$5,998.09**	$1,543.77	-	-	**$5,361.65**	$1,410.71	-$133.06	-8.6%
Education & Human Resources	**$884.10**	-	-	-	**$760.55**	-	-	N/A
Major Research Equipment & Facilities Construction	**$241.50**	$241.48	-	-	**$182.80**	$182.80	-$58.68	-24.3%
Agency Operations & Award Management	**$351.11**	-	-	-	**$328.51**	-	-	N/A
National Science Board	**$4.31**	-	-	-	**$4.37**	-	-	N/A
Office of Inspector General	**$14.76**	-	-	-	**$15.01**	-	-	N/A
Total, National Science Foundation	**$7,493.86**	$1,785.25	-	-	**$6,652.89**	$1,593.51	**-$191.74**	**-10.7%**

NATIONAL SCIENCE FOUNDATION
RESEARCH INFRASTRUCTURE (RI) SUMMARY

National Science Foundation
Research Infrastructure Summary
FY 2018 Budget Request to Congress

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual Amount	Percent
Facilities	**$729.33**	**-**	**$683.94**	**-$45.39**	**-6.2%**
Academic Research Fleet[1]	82.79	-	77.80	-4.99	-6.0%
Arecibo Observatory	8.90	-	7.72	-1.18	-13.2%
AST Portfolio Review Implementation	2.18	-	7.00	4.82	220.9%
Cornell High Energy Synchrotron Source (CHESS)	20.03	-	16.00	-4.03	-20.1%
Gemini Observatory	19.88	-	21.03	1.15	5.8%
Geodesy Advancing Geosciences and EarthScope (GAGE)	13.18	-	12.22	-0.96	-7.3%
IceCube Neutrino Observatory (IceCube)	8.71	-	7.00	-1.71	-19.6%
International Ocean Discovery Program (IODP)	48.00	-	48.00	-	-
Large Hadron Collider (LHC)[2]	20.00	-	22.30	2.30	11.5%
Laser-Interferometer Gravitational-wave Observatory (LIGO)	39.43	-	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)	35.34	-	34.77	-0.57	-1.6%
National Nanotechnology Coordinated Infrastructure (NNCI)	16.33	-	14.78	-1.55	-9.5%
National Superconducting Cyclotron Laboratory (NSCL) (MSU Cyclotron)	24.00	-	23.00	-1.00	-4.2%
Natural Hazards Engineering Research Infrastructure (NHERI)	13.00	-	11.75	-1.25	-9.6%
Ocean Observatories Initiative (OOI)	54.98	-	31.00	-23.98	-43.6%
Other Facilities[3]	3.10	-	2.79	-0.31	-10.1%
Polar Facilities and Logistics	293.82	-	283.16	-10.66	-3.6%
Seismological Facilities for Advancement of Geoscience & EarthScope (SAGE)	25.64	-	24.19	-1.45	-5.7%
Major Research Equipment & Facilities Construction Investments	**$305.54**	**-**	**$265.60**	**-$39.94**	**-13.1%**
Construction, Acquisition, and Commissioning[4]	241.48	-	182.80	-58.68	-24.3%
Development and Design[5]	17.59	-	1.80	-15.79	-89.8%
Initial Operations and Maintenance During Construction[6]	46.47	-	81.00	34.53	74.3%
Federally Funded R&D Centers	**$223.33**	**-**	**$207.76**	**-$15.57**	**-7.0%**
National Center for Atmospheric Research (NCAR)	105.60	-	89.90	-15.70	-14.9%
National Optical Astronomy Observatories (NOAO)	21.99	-	20.67	-1.32	-6.0%
National Radio Astronomy Observatories (NRAO)[7]	81.50	-	76.34	-5.16	-6.3%
Other Astronomical Facilities[8]	-	-	11.85	11.85	N/A
National Solar Observatory (NSO)[9]	9.50	-	5.00	-4.50	-47.4%
Science & Technology Policy Institute (STPI)	4.74	-	4.00	-0.74	-15.6%
Other Research Instrumentation and Infrastructure	**$529.92**	**-**	**$438.67**	**-$91.25**	**-17.2%**
Major Research Instrumentation (MRI)	79.78	-	75.00	-4.78	-6.0%
Midscale Research Infrastructure	49.01	-	20.27	-28.74	-58.6%
National Center for Science & Engineering Statistics (NCSES)	45.21	-	42.64	-2.57	-5.7%
NCSES Science of Science and Innovation Policy (SciSIP) Activities	4.95	-	4.95	-	-
Networking and Computational Resources Infrastructure and Services	129.35	-	117.50	-11.85	-9.2%
Polar Environment, Health, and Safety (PEHS)	7.09	-	6.18	-0.91	-12.8%
Research Resources[10]	213.24	-	170.38	-42.86	-20.1%
Research Resources – Public Access Initiative	1.29	-	1.75	0.46	36.1%
Subtotal, Research Infrastructure Support	**$1,788.12**	**-**	**$1,595.97**	**-$192.15**	**-10.7%**
Research Infrastructure Stewardship Offset	**-$2.87**	**-**	**-$1.16**	**$1.71**	**-59.5%**
RESEARCH INFRASTRUCTURE TOTAL	**$1,785.25**	**-**	**$1,594.81**	**-$190.44**	**-10.7%**

[1] 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.

[2] Large Hadron Collider (LHC) funding on this line includes $6.30 million in FY 2018 for planning for the LHC upgrade, a proposed future MREFC project.

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

[4] Construction, Acquisition, and Commissioning are for implementation support provided through the MREFC account. MREFC funding is included for NEON, DKIST, and LSST in FY 2016; in FY 2018, DKIST, LSST and RCRV are included.

[5] Development and Design includes funding for potential next generation multi-user facilities. This line reflects funding for RCRV in FY 2016 and Antarctic Infrastructure Modernization for Science (AIMS) for both years. Not included here is the Large Hadron Collider (LHC) upgrade, captured under the LHC facilities line in the table.

[6] Initial Operations and Maintenance During Construction are Research and Related Activities (R&RA) funds for these purposes while MREFC construction is ongoing. Funding is included for NEON and DKIST for both years.

[7] 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 shown 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] Other Astronomical Facilities funding includes the Green Bank Observatory and the Very Long Baseline Array, removed from NRAO and ALMA.

[9] National Solar Observatory (NSO) totals presented do not include $11.50 million in FY 2016, and $14.0 million in FY 2018 for operations and maintenance support for the DKIST facility construction project. DKIST funding is captured within the total presented Initial Operations and Maintenance During Construction line.

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

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NATIONAL SCIENCE FOUNDATION CURRENT AUTHORIZATIONS

(Dollars in Millions)

LEGISLATION	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Authorization Levels FY 2016	FY 2017	FY 2018
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*		
American Innovation and Competitiveness Act P.L. 114-329 (Does not authorize appropriations)						
The American Innovation and Competitiveness Act authorizes NSF's research and education programs. The law also promotes NSF's commitment to diversity in STEM fields, and incentivizes NSF programs which encourage private-sector involvement, while re-affirming NSF's continued commitment to entrepreneurship and commercialization.						
SBIR and STTR reauthorized through 2022 at current levels under the National Defense Authorization Act of Fiscal Year 2017, P.L. 114-328						
Small Business Innovation Research (SBIR) Program[2]	**$163.79**	**-**		*3.0% of research funds in 2016, 3.2% in 2017, and 3.2% in 2018*		
Small Business Technology Transfer (STTR) Program[2]	**$24.73**	**-**		*0.45% of research funds in 2016, 2017 and 2018*		
National Windstorm Impact Reduction Act Reauthorization of 2015, P.L. 114-52[3]	**$37.60**	*****	*****	*$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.						

National Science Foundation Current Authorizations
(Dollars in Millions)

				Authorization Levels		
LEGISLATION	**FY 2016 Actual**	**FY 2017 (TBD)**	**FY 2018 Request**	**FY 2016**	**FY 2017**	**FY 2018**
The Research Excellence and Advancements for Dyslexia Act (READ Act), P.L. 114-124	**$12.30**	*	*		*$5.00*	*$5.00*
The National Science Foundation shall support multi-directorate, merit-reviewed, and competitively awarded research on the science of specific learning disability, including dyslexia, such as research on the early identification of children and students with dyslexia, professional development for teachers and administrators of students with dyslexia, curricula and educational tools needed for children with dyslexia, and implementation and scaling of successful models of dyslexia intervention. [4]						

[1] Organic legislation establishing NSF.

[2] SBIR and STTR are reauthorized through September 30, 2022.

[3] Actual amounts will be reported after awards are completed.

[4] The $5.0 million shall include not less than $2.5 million for research on the science of dyslexia, for each of fiscal years 2017 through 2021. FY 2016 Actuals funding includes $2.14 million for dyslexia research.

NATIONAL SCIENCE FOUNDATION (NSF)
COMPUTER SCIENCE EDUCATION RESEARCH CONGRESSIONAL REPORT
IN COMPLIANCE WITH PUBLIC LAW 114-329:
AMERICAN INNOVATION AND COMPETITIVENESS ACT, SEC. 310 (E)

The American Innovation and Competitiveness Act, 2017, Public Law 114-329, requires the National Science Foundation (NSF) to undertake specific activities regarding computer science education research (Sec. 310):

"(b) GRANT PROGRAM.-

(1) IN GENERAL.—The Director of the Foundation shall award grants to eligible entities to research computer science education and computational thinking.

(2) RESEARCH.—The research described in paragraph (1) may include the development or adaptation, piloting or full implementation, and testing of —

(A) models of preservice preparation for teachers who will teach computer science and computational thinking;

(B) scalable and sustainable models of professional development and ongoing support for the teachers described in subparagraph (A);

(C) tools and models for teaching and learning aimed at supporting student success and inclusion in computing within and across diverse populations, particularly poor, rural, and tribal populations and other populations that have been historically underrepresented in computer science and STEM fields; and

(D) high-quality learning opportunities for teaching computer science and, especially in poor, rural, or tribal schools at the elementary school and middle school levels, for integrating computational thinking into STEM teaching and learning.

(c) COLLABORATIONS.—In carrying out the grants established in subsection (b), eligible entities may collaborate and partner with local or remote schools to support the integration of computing and computational thinking within pre-kindergarten through grade 12 STEM curricula and instruction.

(d) METRICS.—The Director of the Foundation shall develop metrics to measure the success of the grant program funded under this section in achieving program goals.

(e) REPORT.—The Director of the Foundation shall report, in the annual budget submission to Congress, on the success of the program as measured by the metrics in subsection (d).

(f) DEFINITION OF ELIGIBLE ENTITY.—In this section, the term "eligible entity" means an institution of higher education of a non-profit research organization."

Background

NSF launched the Computer Science for All: Researcher Practitioner Partnerships (CS for All: RPP) program with solicitation NSF 17-525. The CS for All: RPP program synopsis in the program solicitation states that:

"This program aims to provide all U.S. students the opportunity to participate in computer science (CS) and computational thinking (CT) education in their schools at the K-12 levels. With this solicitation, the National Science Foundation (NSF) focuses on researcher-practitioner partnerships (RPPs) that foster the research and development needed to bring CS/CT to all schools. Specifically, this solicitation aims to provide high school teachers with the preparation, professional development (PD) and ongoing support that they need to teach rigorous computer science courses, and K-8 teachers with the instructional materials and preparation they need to integrate CS/CT into their teaching."

The program's first deadline for proposals was February 28, 2017. NSF convened merit review panels in April 2017, and the program will make its first cohort of two- to four-year awards by the end of FY 2017. It is premature to report on the success of this grant program, but the substance of short-, mid-, and longer-term metrics for success is discussed below.

Metrics
Short-term metrics will focus on ensuring that the program is making awards in the four areas outlined in the law and that the awards address the goal of broadening participation in computer science. One indicator of broadening participation is the diversity of the populations targeted in the awards.

Mid-term metrics will include the extent to which funded projects are achieving goals as measured by the progress reported in NSF's required annual and final project reports.

Longer-term (after five years) metrics will include an evaluation of the outcomes of the program, which are based on the program aims as described in the program solicitation and the well-aligned requirements of Public Law 114-329. Program staff are working with the Evaluation and Monitoring Group within the NSF Directorate for Education and Human Resources and the Evaluation and Assessment Capability Section within the NSF Office of Integrative Activities to develop (1) a set of specific longer-term metrics and (2) a program evaluation plan for measuring the collective success of the CS for All: RPP projects on these longer-term metrics.

NATIONAL SCIENCE FOUNDTION (NSF)
ESTABLISHED PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCOR)
CONGRESSIONAL REPORT
IN COMPLIANCE WITH PUBLIC LAW 114-329:
AMERICAN INNOVATION AND COMPETITIVENESS ACT, SEC. 103 (d) (1-3)
FISCAL YEAR 2016

This report summarizes fiscal year (FY) 2016 NSF funding to institutions and entities in EPSCoR jurisdictions, as required by the American Innovation and Competitiveness Act Sec. 103 (d) (1-3). Specifically, the report itemizes:
(1) a description of the program strategy and objectives
(2) a description of the awards made in the previous fiscal year including:
(A) the total amount made available, by state, under EPSCoR
(B) the total amount of agency funding made available to all institutions and entities within each EPSCoR state
(C) the efforts and accomplishments to more fully integrate the EPSCoR states in major agency activities and initiatives
(D) the percentage of EPSCoR reviewers from EPSCoR states
(E) the number of programs or large collaborator awards involving a partnership of organizations and institutions from EPSCoR and non-EPSCoR states
(3) an analysis of the gains in academic research quality and competitiveness, and in science and technology human resource development, achieved by the program over the last 5 years.

Introduction
EPSCoR utilizes three investment strategies in pursuit of its goal to strengthen research capacity and competitiveness in eligible jurisdictions. These investment strategies are: (1) Research Infrastructure Improvement (RII) awards that support physical, human, and cyber infrastructure development; (2) Co-Funding in partnership with National Science Foundation (NSF) directorates and offices that support individual investigators and groups within EPSCoR jurisdictions; and (3) Outreach Activities and Workshops that bring EPSCoR jurisdiction investigators together with program staff from across the Foundation to explore opportunities in emerging areas of science and engineering aligned with NSF strategic priorities and with jurisdictional science and technology goals.

EPSCoR Strategies and Objectives (Sec. 103(d)(1))
EPSCoR's strategies and objectives in FY 2016 remained the same as those described in the FY 2015 report. Specifically, the mission of EPSCoR is "to advance excellence in science and engineering research and education in order to achieve sustainable increases in research, education, and training capacity and competitiveness that will enable EPSCoR jurisdictions to have increased engagement in areas supported by the NSF." Thus, EPSCoR's goals are:

- To catalyze the development of research capabilities and the creation of new knowledge that expands jurisdictions' contributions to scientific discovery, innovation, learning, and knowledge-based prosperity.
- To establish sustainable Science, Technology, Engineering and Math (STEM) education, training, and professional development pathways that advance jurisdiction-identified research areas and workforce development.
- To broaden direct participation of diverse individuals, institutions, and organizations in the project's science and engineering research and education initiatives.
- To effect sustainable engagement of project participants and partners, the jurisdiction, the national research community, and the general public through data-sharing, communication, outreach, and dissemination.

- To impact research, education, and economic development beyond the project at academic, government, and private sector levels.

NSF Funding Made Available, by State, under EPSCoR (Sec. 103(d)(2)(A))
In FY 2016, NSF EPSCoR invested a total of $160.03 million in support of its programmatic activities. Of this, $131.00 million (81.8 percent) was directed to RII, $27.90million (17.4 percent) to co-funding, and $1.13 million (0.7 percent) to outreach activities and workshops. The table below details the investments from EPSCoR resources, and EPSCoR investments in co-funding actions.

NSF funding made available, by State, under EPSCoR

(Dollars in Millions)

EPSCoR Jurisdiction	RII program	Outreach & workshops[1]	EPSCoR cofunding	EPSCoR Total
AK	-	-	$0.27	$0.27
AL	-	0.32	3.16	3.48
AR	8.00	-	0.49	8.49
DE	14.00	0.10	1.26	15.36
GU	2.09	-	-	2.09
HI	4.00	-	1.16	5.16
ID	-	0.04	1.24	1.28
KS	3.90	-	0.60	4.50
KY	3.84	0.04	1.17	5.05
LA	14.00	-	1.57	15.57
ME	3.00	-	0.94	3.94
MO	-	0.04	1.71	1.75
MS	10.00	-	1.41	11.41
MT	10.00	0.46	1.18	11.64
ND	8.00	-	0.91	8.91
NE	4.00	-	1.96	5.96
NH	6.00	-	-	6.00
NM	-	0.04	1.49	1.53
NV	4.00	0.04	0.19	4.23
OK	4.00	-	1.98	5.98
PR	5.00	-	0.51	5.51
RI	1.44	-	0.45	1.89
SC	6.00	-	1.28	7.28
SD	-	-	0.63	0.63
VI	4.00	-	-	4.00
VT	4.00	-	-	4.00
WV	4.00	-	1.76	5.76
WY	4.00	-	0.36	4.36
Admin	3.73	0.05	0.22	4.00
Total	**$131.00**	**$1.13**	**$27.90**	**$160.03**

Total NSF Funding Made Available in all EPSCoR Jurisdictions (Sec. 103 (d)(2)(B))
In FY 2016, NSF invested a total of $711.69 million in support of EPSCoR jurisdictions. The table below details NSF investments in EPSCoR jurisdictions.

NSF funding made available to all EPSCoR jurisdictions

(Dollars in Millions)

EPSCoR Jurisdiction	NSF Funding
AK	$34.39
AL	26.40
AR	18.61
DE	44.61
GU	2.11
HI	33.66
ID	16.07
KS	30.40
KY	27.03
LA	40.90
ME	13.27
MO	58.79
MS	20.94
MT	29.02
ND	15.69
NE	25.02
NH	39.84
NM	40.33
NV	14.96
OK	25.36
PR	12.46
RI	38.41
SC	55.88
SD	6.49
VI	4.25
VT	8.61
WV	12.45
WY	15.76
Total	**$711.69**

Integration of EPSCoR Jurisdictions in Major Activities and Initiatives of the Foundation (Sec. 103 (d)(2)(C))
All EPSCoR programmatic activities target integration and assimilation of EPSCoR jurisdictions into the research and education programs of the Foundation's disciplinary directorates. RII awards enhance academic research capacity and promote the coordination and integration of recipient jurisdictions into major NSF programmatic activities. Additionally, EPSCoR engages NSF disciplinary program officers (PO) in merit review and post-award evaluations, such as site visits and reverse site visits (RSVs). Site visits and RSVs are intended to provide additional project oversight by allowing jurisdictions to report on the progress of their RII Track- 1projects in relation to their stated goals and the programmatic terms and conditions. Disciplinary POs assist in the identification of reviewers, serve as site visit and RSV panelists, and provide knowledge about the ongoing activities within the directorate that could be leveraged to sustain RII efforts after the performance period of the EPSCoR award.

National, regional, and jurisdictional meetings of the EPSCoR community facilitate interactions with NSF leadership to learn about the Foundation's strategic priorities and funding opportunities. Participation by EPSCoR researchers and educators in the merit review process across all disciplinary domains of the Foundation, in Committees of Visitors (COV) activities, in external advisory (Federal Advisory Committee Act) committees, and in disciplinary workshops that shape new activities is also vital to this integration.

Outreach to EPSCoR jurisdictions by NSF staff promotes integration of the EPSCoR community into mainstream NSF programs, as does co-funding of awards with disciplinary programs of the Foundation. There is also an effort to promote in-reach, whereby EPSCoR facilitates opportunities for researchers and educators from EPSCoR jurisdictions to meet with NSF staff at the Foundation's headquarters. In these meetings, the EPSCoR participants are provided with information of NSF strategic priorities and funding opportunities, as well as meet with disciplinary POs. In FY 2016, EPSCoR staff facilitated approximately 35 in-reach meetings.

In FY 2016, EPSCoR staff sought to promote engagement of the EPSCoR community in NSF and other national activities. Examples are:

- In FY 2016, EPSCoR continued its efforts to better communicate the "EPSCoR success story" by continuing its communication workshop, "Becoming an EPSCoR Champion," which targets RII Track-1 researchers to specifically emphasize successful outcomes of EPSCoR research. This workshop series helps researchers cultivate communication skills through disciplined, systematic messaging to convey an influential, economically-framed message that effectively signals the value of EPSCoR's activities. It seeks to enhance abilities to deliver the jurisdiction's scientific messages effectively, charismatically, and successfully.
- NSF EPSCoR has continued to encourage the involvement of EPSCoR-supported faculty in NSF committee and review panels across NSF (e.g., COVs, site visits, and merit review panels).
- EPSCoR continued its RII Track-2: Focused EPSCoR Collaborations (RII Track-2 FEC) solicitation. RII Track-2 FEC builds interjurisdictional collaborative teams of EPSCoR investigators in scientific focus areas consistent with NSF priorities, including cognitive science and neuroscience, clean energy, and food security. In addition, these awards have a particular focus on the development of early career/junior faculty. Eleven awards were made in FY 2016.

EPSCoR Reviewers (Sec. 103(d)(2)(D))
Demographics of all reviewers who evaluated EPSCoR proposals or the program in FY 2016 are as follows: of the 149 reviewers, 24 percent were underrepresented minorities, 47 percent were female, 19 percent were from EPSCoR jurisdictions, 83 percent were new reviewers for the EPSCoR program (most had prior NSF review experience), and 9 percent were new reviewers from EPSCoR jurisdictions.

EPSCoR Collaborations and Partnerships (Sec. 103(d)(2)(E))

All RII awards involve collaborations among scientists and engineers in EPSCoR jurisdictions. Additionally, RII awards require institutional collaborations, which are defined as collaborations between researchers at a RII awardee or sub-awardee and those at institutions not receiving any RII funds.

In FY 2016, there were 909 institutional collaborations within EPSCoR jurisdictions; 774 institutional collaborations between EPSCoR jurisdictions and other EPSCoR and non-EPSCoR jurisdictions; and 255 international institutional collaborations with EPSCoR jurisdictions. These efforts highlight the vast network of institutional involvement among EPSCoR jurisdictions and their partners in RII projects.

Among the 160 awards co-funded by EPSCoR in FY 2016, 82 involved collaborative research between multiple institutions. Of those 82 collaborative awards, 34 were collaborations between investigators from institutions in EPSCoR and non-EPSCoR jurisdictions.

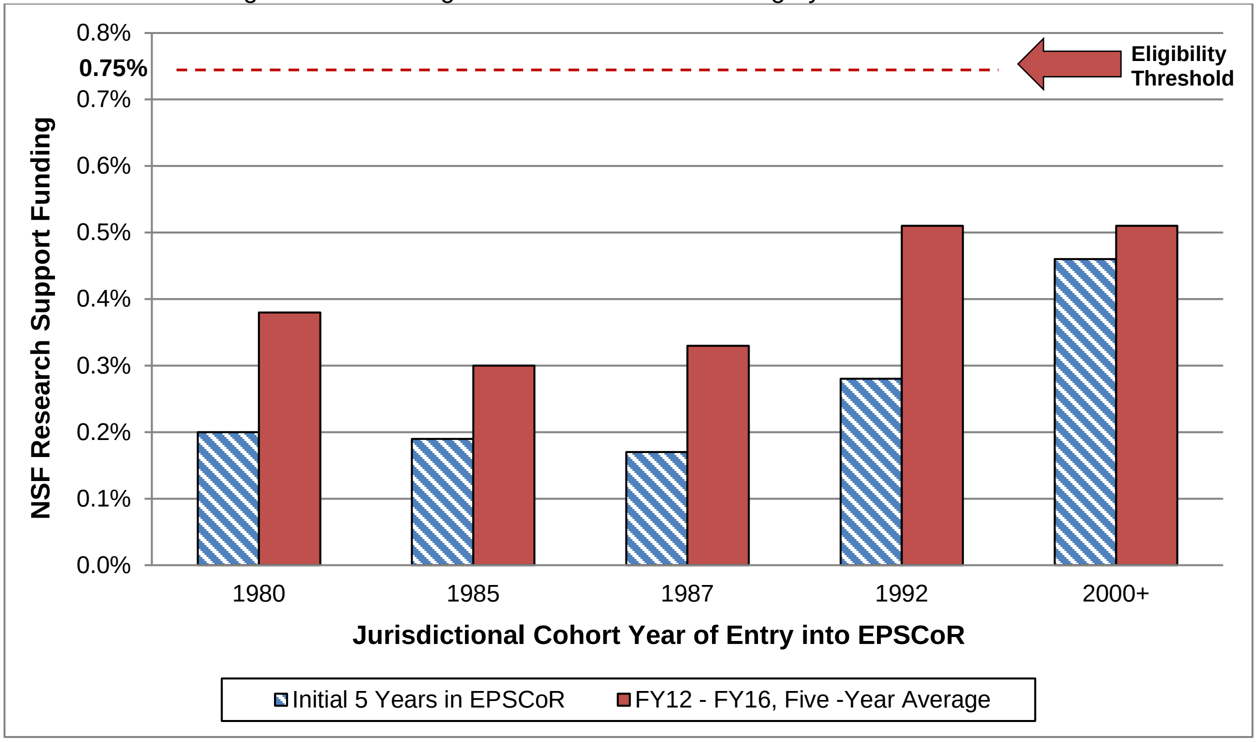
An analysis of the gains in academic research quality and competitiveness, and in science and technology human resource development, achieved by the program over the last 5 fiscal years (Sec. 103(d)(3))

Eligibility to participate in NSF EPSCoR programmatic activities is based upon the jurisdictions' demonstrated ability to obtain NSF research funds. Currently, a jurisdiction is eligible to participate in EPSCoR programs if its level of NSF research support is equal to or less than 0.75 percent of the total NSF research and related activities budget averaged over the most recent three year period.

Given EPSCoR's aim to stimulate research that is fully competitive in NSF's disciplinary and multidisciplinary research programs, increases in the ability to capture NSF research funds serve as a proxy for gains in research competitiveness. In FY 2016, the 3-year rolling average of NSF research funds for Iowa, Missouri, Tennessee, and Utah was over the 0.75 percent threshold and these jurisdictions were no longer eligible to compete in new RII competitions. Additionally, Iowa, Tennessee, and Utah exceeded the threshold for three consecutive years and were no longer EPSCoR-eligible for co-funding or outreach in FY 2016.

Figure 1 (below) shows the average amount of NSF research funds by cohort for the initial five years (hatched bars) and the most recent five years (solid bars) of their participation in the NSF EPSCoR Program. A cohort is defined as the group of states or jurisdictions that entered the EPSCoR program within a given fiscal year. For example, the 1980 cohort consists of the initial five states that qualified for EPSCoR: Arkansas, Maine, Montana, South Carolina, and West Virginia. For this summary, the 2000+ cohort consists of jurisdictions that entered EPSCoR in FY 2000 or later: Alaska, Delaware, Guam, Hawaii, Missouri, New Hampshire, New Mexico, Rhode Island, and the U.S. Virgin Islands. Former EPSCoR jurisdictions Iowa, Tennessee, and Utah are excluded because they were no longer EPSCoR-eligible in FY 2016.

Figure 1. Percentage of NSF Research Funding by EPSCoR Cohort



Each cohort shows an increase in competitiveness over the periods of participation. For example, the 1980 cohort shows a 90 percent increase in NSF research funding over the past 36 years of EPSCoR activity. The 1985 cohort (Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Puerto Rico, Vermont, and Wyoming) demonstrates a 58 percent increase during its 31 years of participation in EPSCoR. The 1987 cohort (Idaho, Louisiana, Mississippi, and South Dakota) shows a 94 percent increase over the past 29 years, while the 1992 cohort (Kansas and Nebraska) has an 82 percent increase in competitiveness over its 24 years of EPSCoR involvement. Jurisdictions participating in EPSCoR since FY 2000 entered into the program at a higher level of NSF research funding than the previous cohorts. For the 2000+ cohort, there has been a small, yet demonstrable 11 percent increase in research funding. The data for each jurisdiction is provided in the table immediately after the figure.

Percentage of NSF Research Support Funding, by Jurisdiction and EPSCoR Cohort

	Initial 5 Years in EPSCoR	Most Recent 5 Year Period (FY 2012-2016)
1980 Cohort	0.20%	0.38%
Arkansas	0.10%	0.32%
Maine	0.27%	0.34%
Montana	0.13%	0.37%
South Carolina	0.41%	0.63%
West Virginia	0.07%	0.24%
1985 Cohort	0.19%	0.30%
Alabama	0.33%	0.47%
Kentucky	0.22%	0.39%
Nevada	0.14%	0.29%
North Dakota	0.06%	0.18%
Oklahoma	0.30%	0.51%
Puerto Rico	0.15%	0.12%
Vermont	0.10%	0.17%
Wyoming	0.20%	0.25%
1987 Cohort	0.17%	0.33%
Idaho	0.08%	0.25%
Louisiana	0.36%	0.58%
Mississippi	0.16%	0.27%
South Dakota	0.09%	0.21%
1992 Cohort	0.28%	0.51%
Kansas	0.34%	0.58%
Nebraska	0.22%	0.44%
2000+ Cohort	0.46%	0.51%
Alaska	0.55%	0.51%
Delaware	0.41%	0.57%
Guam	0.02%	0.02%
Hawaii	0.56%	0.56%
Missouri	0.88%	0.87%
New Hampshire	0.44%	0.60%
New Mexico	0.58%	0.66%
Rhode Island	0.70%	0.70%
Virgin Islands	0.00%	0.06%

The table below demonstrates the quantifiable outputs of NSF EPSCoR's RII Track-1 program over the last 5 fiscal years. This information elucidates the gains in academic research quality over time, as defined by publications, leveraged grants, and patents. For publications, primary support is defined as research that is directly funded by EPSCoR and partial support is defined as use of equipment or facilities funded by EPSCoR. The number and valuation of grants awarded encompasses all federal, private industry, and private foundation awards across the U.S. in a given fiscal year for all EPSCoR jurisdictions.

Aggregate of EPSCoR Outputs (n=31*)

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Total
Primary Support Publications	543	679	591	581	409	2,803
Partial Support Publications	1,237	1,254	1,001	1,026	927	5,445
Grants Awarded	640	654	601	563	675	3,133
Value of Grants Awarded ($M)	$264.3	$259.5	$278.8	$181.8	$379.1	$1,363.5
Patents Awarded	22	12	15	13	14	76
Patents pending	49	55	38	44	34	220

*The maximum number of jurisdictions with active RII Track-1 awards in any given fiscal year. Outputs are not comparable from year-to-year due to the influx of new and expiring awards over the time period.

The table below indicates EPSCoR's ongoing support of human resource development over the last 5 fiscal years in the RII Track-1 program. The number of faculty and students involved in RII Track-1 projects have remained fairly constant over time, signifying a strong commitment by NSF and the jurisdictions in strengthening jurisdictional human capital in science and engineering research and education.

EPSCoR Human Resource Development

	FY12	FY13	FY14	FY15	FY16	Total
Faculty Supported	1,461	1,535	1,581	1,602	1,552	N/A*
Post-Docs Supported	211	211	215	231	200	N/A*
Graduate Students Supported	1,443	1,383	1,346	1,361	1,332	N/A*
Undergraduates Supported	1,769	1,955	1,867	1,965	1,861	N/A*
New Faculty Hired	79	60	73	89	84	385
Graduate Degrees Conferred	233	305	326	245	258	1,367
Undergraduate Degrees Conferred	425	376	380	408	404	1,993

* The number of faculty and students supported are not summed because many of them remain tied to their respective projects for the duration of the award and would, therefore, be double-counted over time.

Additionally, NSF EPSCoR is working with NSF's Evaluation and Assessment Capability Section to develop a cohesive evaluation framework for the program. This evaluation will address the legislative objective of increasing the research competitiveness of jurisdictions receiving EPSCoR funding. The evaluation is informed by the findings and recommendations from the EPSCoR retrospective evaluation completed by the Science and Technology Policy Institute (STPI) in 2012. Part of this effort involves developing an evaluation contract that will (1) develop a flexible framework to explore, define, and measure research competitiveness in relation to the unique jurisdictional contexts and (2) use evidence of jurisdictional progress toward research competitiveness over time for strategic program improvement.

RESEARCH AND RELATED ACTIVITIES (R&RA) $5,361,650,000

-$636,440,000 / -10.6%

The FY 2018 Budget Request for the Research and Related Activities (R&RA) account is $5,361.65 million a decrease of $636.44 million (10.6 percent) below the FY 2016 Actual. Funding within the R&RA Appropriation enables U.S. leadership and progress across the frontiers of scientific and engineering research and education.

In FY 2018, 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.

R&RA Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Biological Sciences	$723.78	-	$672.11	-$51.67	-7.1%
Computer & Information Science & Engineering	935.20	-	838.92	-96.28	-10.3%
Engineering	915.68	-	833.49	-82.19	-9.0%
Geosciences	876.51	-	783.31	-93.20	-10.6%
Mathematical & Physical Sciences	1,348.78	-	1,219.43	-129.35	-9.6%
Social, Behavioral & Economic Sciences	272.20	-	244.02	-28.18	-10.4%
Office of International Science and Engineering	49.07	-	44.02	-5.05	-10.3%
Office of Polar Programs	448.87	-	409.18	-39.69	-8.8%
Integrative Activities	426.57	-	315.74	-110.83	-26.0%
U.S. Arctic Research Commission	1.43	-	1.43	-	-
Total, R&RA	**$5,998.09**	**$6,022.18**	**$5,361.65**	**-$636.44**	**-10.6%**

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,~~*$5,361,650,000,* to remain available until September 30, ~~2017,~~*2019,* of which not to exceed ~~$540,000,000~~*$500,000,000* 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.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Research and Related Activities
FY 2018 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 2016 Appropriation	$6,033.65	$10.08	-$11.93	$10.26	-$43.97	$5,998.09
FY 2017 Annualized CR	6,022.18	11.93				6,034.11
FY 2018 Request	5,361.65					5,361.65
$ Change from FY 2017 Annualized CR						-$672.46
% Change from FY 2017 Annualized CR						-11.1%

Explanation of Carryover

Within the **Research and Related Activities (R&RA)** account, $18.23 million (including $6.30 million in reimbursable funds) was carried over into FY 2017.

Directorate for Geosciences Polar Programs (no-year funding)

- Amount: $2.06 million
- Reason: Recoveries from prior year obligations that were received too late in the fiscal year to obligate.
- Obligated: FY 2017 Quarter 2

Integrative Activities (IA)

- Amount: $6.33 million
- Reason: The complexity of co-funding for several INSPIRE awards prevented the timely obligation of these funds.
- Anticipated Obligation: FY 2017 Quarter 3

- Amount: $199,402
- Reason: Processing a new awardee in the Major Research Instrumentation Program delayed obligating the award.
- Anticipated Obligation: FY 2017 Quarter 3

National Coordination Office for Networking and Information Technology Research and Development (NCO/NITRD)

- Amount: $617,984
- Reason: NCO was unable to secure a lease with GSA in time to obligate the funds. The Reimbursable Work Authorization was completed in November 2016.
- Obligated: FY 2017 Quarter 1

National Nanotechnology Coordination Office (NNCO)

- Amount: $215,012
- Reason: NNCO's planned move and the timing of GSA's negotiation of the new lease precluded obligating the funds in FY 2016. In addition, carryover funding was needed to cover costs to complete the required Nuclear Regulatory Commission study.
- Obligated: FY 2017 Quarter 1

The remaining R&RA carryover of $2.50 million consists of funds from throughout the Foundation for projects that were not ready for obligation in FY 2016.

DIRECTORATE FOR BIOLOGICAL SCIENCES (BIO) $672,110,000
-$51,670,000 / -7.1%

BIO Funding

(Dollars in Millions)

	FY 2016 Actual[1]	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Molecular & Cellular Biosciences (MCB)	$135.46	-	$123.21	-$12.25	-9.0%
Integrative Organismal Systems (IOS)	214.21	-	111.20	-103.01	-48.1%
Enviornmental Biology (DEB)	143.96	-	130.78	-13.18	-9.2%
Biological Infrastructure (DBI)	144.61	-	169.61	25.00	17.3%
Emerging Frontiers (EF)	85.53	-	137.31	51.78	60.5%
Total	**$723.78**	**-**	**$672.11**	**-$51.67**	**-7.1%**

[1] In FY 2016, $20.0 million was transferred from EF to the MREFC account for increased NEON construction costs. Including this transfer, BIO's total funding in FY 2016 was $743.78 million. FY 2018 Request funding for BIO compared to BIO's initial FY 2016 budget is a decrease of $71.67 million or 9.6 percent.

About BIO

BIO has three overarching goals:

- To support research to advance understanding of the principles and mechanisms governing life;
- To increase our understanding of complex interactions between living systems and their environments; and
- To provide real and theoretical bases for original research in other scientific disciplines and for application of science to improve the quality of life.

The FY 2018 Budget Request for BIO is $672.11 million. Special emphasis will be placed on research that aligns with the comprehensive BIO framework, Understanding the Rules of Life (URoL) that will address major challenges in biology. These include understanding living systems across scales of size, time and place, and the complex relationships between genotype and phenotype in plants, animals, and microbes. 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. U.S. academic research in the biological sciences depends on NSF funding; 69 percent of academic basic research in non-medical biology is supported by NSF. BIO considers this role essential to the promotion of vibrant and innovative fundamental biological research at U.S. universities and colleges, noting that BIO's programs support the real and theoretical bases for original research in other scientific disciplines as well as downstream applications of potential societal benefit. Broad support for biology is necessary to produce knowledge relevant to national needs in food, health, energy, and environment. Additionally, support for biological research will continue a stream of economic innovations that contribute to American livelihoods, as demonstrated by 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. 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 effective integration requires new funding strategies and portfolio realignment within BIO. These strategies are reflected in the FY 2018 Budget Request.

FY 2018 priorities for BIO include:

Understanding the Rules of Life (URoL): First introduced in FY 2017, support for URoL will continue in FY 2018 emphasizing research areas such as the genotype to phenotype challenge, plant-organismal interactions, 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 continue to be encouraged.

National Ecological Observatory Network (NEON): Construction of NEON is expected to be complete by the spring of 2018 and BIO will assume full responsibility for operations and maintenance (O&M), including increased funding for oversight. In FY 2018, NEON O&M funding moves from EF to DBI in accordance with the shift in program management and oversight that occurred in FY 2017. Funding for early NEON science, including continuing support for the MacroSystems Biology (MSB) program, remains a priority. For more information on NEON, see the Major Research Equipment and Facilities Construction (MREFC) chapter.

Understanding the Brain (UtB), including the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative: This cross-agency priority will be continued in FY 2018. BIO funding for UtB, including the BRAIN Initiative, will support investment strategies designed to enable the transformational research, engineering, infrastructure development, and training required to accomplish the overall multi-year goal. Support for neuroscience activities will focus on the Next Generation Networks for Neuroscience (NeuroNex) program. Additional information for UtB is available in the NSF-Wide Investments chapter.

Innovation: In FY 2018, through funding in EF, BIO will continue investments in innovation activities with a focus on URoL. These activities will build on the interagency agreement, signed in FY 2016 by NSF and the National Aeronautics and Space Administration (NASA) that encourages and supports interaction among NASA and NSF personnel on origins of life research and the joint Ideas Lab on the Origins of Life held in FY 2016 and the ensuing research funded in FY 2017.

Major Investments

BIO Major Investments

(Dollars in Millions)

				Change Over FY 2016 Actual	
Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Amount	Percent
CAREER	$45.68	-	$35.07	-$10.61	-23.2%
CEMMSS	5.48	-	5.48	-	-
Advanced Manufacturing	*3.33*	-	*3.33*	-	-
NSF I-Corps™	1.00	-	1.00	-	-
NSF INCLUDES	1.40	-	1.40	-	-
IUSE	2.74	-	2.50	-0.24	-8.7%
Understanding the Brain	33.51	-	46.00	12.49	37.3%
BRAIN Initiative	*9.06*	-	*19.54*	*10.48*	*115.7%*

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

All funding decreases/increases represent changes over the FY 2016 Actual.

- Faculty Early Career Development (CAREER) (-$10.61 million to a total of $35.07 million): BIO's CAREER awards support 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.

- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) (no change; total of $5.48 million): BIO's support will enable development of breakthrough materials through research on topics such as computational mining of genomic data from diverse biological systems to identifying 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 2018, BIO will continue its interagency collaborations in the area of engineering biology related to advanced biomanufacturing. The Directorate for Engineering (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 (no change; total of $3.33 million): BIO will continue support for advanced manufacturing research. 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.

- NSF Innovation Corps (I-Corps™) (no change; total of $1.0 million): BIO will sustain support for I-Corps™ nodes and teams 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) (no change; total of $1.40 million): In FY 2018, BIO will continue to 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.

- Improving Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education (IUSE) (-$240,000 to a total of $2.50 million): BIO 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.

- Understanding the Brain (UtB) (+$12.49 million to a total of $46.0 million): BIO will increase 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 (+$10.48 million to a total of $19.54 million): As part of UtB, BIO will increase support for the BRAIN Initiative to support the Next Generation Networks for Neuroscience (NeuroNex) program.

BIO Funding for Centers Programs and Facilities

BIO Funding for Centers Programs

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual	
				Amount	Percent
Total, Centers Programs	**$33.76**	**-**	**$21.00**	**-$12.76**	**-37.8%**
Centers for Analysis & Synthesis (DBI)	18.40	-	6.00	-12.40	-67.4%
Nanoscale Science & Engineering Centers (DBI)[1]	5.36	-	-	-5.36	-100.0%
STC: Bio/computational Evolution in Action CONsortium (BEACON) (DBI)	5.00	-	5.00	-	-
STC: Center for Biology with X-Ray Lasers (XFel) (DBI)	5.00	-	5.00	-	-
STC: Center for Cellular Construction (CCC) (DBI)	-	-	5.00	5.00	N/A

[1] The Nanoscale Centers program will sunset as planned in FY 2017.

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

BIO Funding for Facilities

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual	
				Amount	Percent
Total, Facilities	**$38.32**	**-**	**$69.35**	**$31.03**	**81.0%**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.35	-	0.35	-	-
Cornell High Energy Synchrotron Source (CHESS)	5.00	-	4.00	-1.00	-20.0%
National Ecological Observatory Network (NEON)	32.97	-	65.00	32.03	97.1%

For detailed information on individual facilities, see the Facilities and the Major Research Equipment and Facilities Construction chapters.

Funding Profile

BIO supports investment in core research and education as well as research infrastructure.

In FY 2018, the number of research grant proposals received is anticipated to remain unchanged from the prior year and BIO expects to award about 900 research grants. The average annual award size and duration are not expected to materially fluctuate in FY 2018.

In FY 2018, BIO will invest $21.0 million in research centers, accounting for 3.1 percent of the BIO budget. This total is down from FY 2016 Actual as several centers have sunset as planned. BIO's FY 2018 Request funds one Center for Analysis and Synthesis, the National Socio-Environmental Synthesis Center (SESync), and the three Science and Technology Centers (An NSF Center for the Study of Evolution in Action (BEACON), X-Ray Free Election Lasers (XFEL), and Center for Cellular Construction (CCC)).

O&M funding for BIO-supported facilities is 10.3 percent of BIO's FY 2018 Request. Support of facilities operations increases in FY 2018 as NEON construction is expected to complete and BIO assumes full responsibility for O&M, including increased funding for oversight. NEON, the only BIO-managed facility, comprises 9.7 percent of BIO's FY 2018 Request.

BIO Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	5,211	-	5,200
Number of New Awards	1,335	-	1,200
Funding Rate	26%	-	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	4,328	-	4,400
Number of Research Grants	959	-	900
Funding Rate	22%	-	20%
Median Annualized Award Size	$200,605	-	$200,600
Average Annualized Award Size	$246,358	-	$246,400
Average Award Duration, in years	3.2	-	3.2

Program Monitoring and Evaluation

Since 2014, BIO has followed and maintained a Transparency and Accountability Plan that enables the directorate to build on prior best practices. This plan includes requirements for post-panel briefings to discuss proposed awards and declinations as well as analysis of the programs' current portfolio of awards for scientific and demographic information; submission of annual prior-year activity reports to BIO's Office of the Assistant Director by each division which are then summarized into a directorate-wide report; and annual directorate-level portfolio analysis by the BIO Portfolio Analysis Working Group.

External Program Evaluations and Studies:

- DEB and IOS, working through the NSF Division of Acquisition and Cooperative Support, awarded a one-year contract in March 2016 to Abt Associates to conduct an external evaluation of the preliminary proposal review mechanism for core programs in the two BIO divisions. The final report was submitted to DEB and IOS in March 2017. The evaluation addressed both program and research community questions about the outcomes of the preliminary proposal mechanism on the research portfolio and the quality of merit review. The report is being reviewed internally and DEB and IOS plan to formulate a response that will be shared with the scientific community within CY 2017.
- Starting in FY 2017, BIO undertook an internal analysis of the programmatic activities of two biological infrastructure programs: Collections in Support of Biological Research and Instrument Development for Biological Research. The outcomes of this analysis will be used to determine the future directions of these two programs and it is anticipated that a summary of the major conclusions will be released in the fourth quarter of FY 2017.

Workshops and Reports:

- Division of Molecular and Cellular Biosciences
    - MCB continued it support of workshops on the topic of reproducibility in biological sciences. In February 2017, NSF's Directorate for Mathematical and Physical Sciences (MPS), Directorate for Computer and Information Science and Engineering (CISE), BIO and the National Institute of Standards and Technology (NIST) convened a workshop titled: "Robustness, Reliability, and Reproducibility in Scientific Research". The resultant report lays out a strategy to engage the community in developing standards and best practices broadly across science.

- A workshop co-funded by MCB, ENG, and DEB titled: "Gene Drives: A Deliberative Workshop to Develop Frameworks for Research and Governance" held February 2016, addressed 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. This workshop will be important in setting up mechanisms for governance of this powerful but potentially high risk/dual use technology.
- 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).
- Two workshops in CY 2016 focused on broadening participation in MCB science: the "Youth Bioinformatics Symposium" in summer 2016, and the "A Strategic Planning Workshop to Explore Quantitative Biology as a Vehicle for Broadening Participation" held at Spelman College in March, 2016. These activities both engage a broader community and provide reports that provide guidance to MCB as it plans its strategic investments.

- Division of Integrative Organismal Systems
  - A workshop titled "Unpacking the Phenotype (UP): Deciphering Genome to Phenome Relationships–Interdisciplinary Research at the Interface of the Biological and Mathematical Sciences" was held in October 2015. This workshop was jointly supported by IOS, MCB, and the Division of Mathematical Sciences (DMS) in MPS to identify opportunities where mathematical modeling approaches would enhance our understanding of multi-scale integration and emergent properties of organisms. A working group formed as a result of this workshop developed recommendations that have led IOS and MCB in BIO and DMS in MPS to initiate a joint venture with the Simons Foundation in New York, NY. Support for center-scale projects focused on the Mathematics of Complex Biological Systems will begin in FY 2018.
  - In FY 2018 IOS anticipates support of additional workshops centered on URoL that unify the biological sciences at NSF. Topics will include high throughput phenotyping and the development of implantable nano-sensors, and epigenetic mechanisms underlying robustness and resilience of organisms to environmental change.

- Division of Environmental Biology
  - A symposium titled: Insect Effects on Ecosystem Services, held September 25-30, 2016, introduced entomologists to broader perspectives on the variety of roles insects play in the delivery of ecosystem services and informed DEB on broader impacts of research investments in insect ecology.
  - A meeting titled: Undergraduates Phenotyping Arabidopsis Knockouts (unPAK) Student Meeting, held June 15-17, 2016, highlighted the development of new techniques for research, comparison of data collection and analysis techniques between institutions, discussion of ways to integrate this research into classroom settings.
  - Two workshops titled, "Forming an integrated understanding of function across fungi", held in August 2016 and March 2017, brought together biologists studying disparate fungi to develop standards and protocols for comparative studies, especially with respect to genetic sequencing and trait databases. These best practices will enhance data management plans (required as part of full proposals submitted to NSF) from the broader community.
  - In spring 2017, "A Workshop to Explore the Shifting Landscape of Research on Biological Diversity" will bring together U.S. scientists for the purpose of understanding the research

implications of the Nagoya Protocol, which calls for sharing of benefits from the use of genetic resources.

- In 2017, a workshop "Addressing Data Management Challenges within Integrative Biodiversity Projects" will bring together participants from Dimensions of Biodiversity projects to discuss the challenges in making biodiversity data more comparable across terrestrial to marine systems, past and present time-scales, cellular to ecosystem levels of biological organization, and diverse geographical regions.

- Division of Biological Infrastructure
  - A conference titled “Coordinating Global Brain Projects”, co-sponsored by DBI and the Kavli Foundation, was held in September 2016 at The Rockefeller University, NY. This conference led to reports in several high-profile journals. The information gleaned from this conference and its subsequent reports are shaping how BIO works with the Office of International Science and Engineering (OISE) to engage funding agencies from the UK, Germany, Japan, Canada, and Israel as partners for NSF’s NeuroNex program.
  - A workshop titled, “Optimizing NEON Science” was held in February 2016 in Boulder, CO to highlight areas of opportunity for community engagement of NEON with the research community. White papers documenting the discussions are in preparation, and workshop participants have already begun effective collaborations and a follow-on activity specifically targeted at early-stage researchers is being scheduled.
  - A workshop titled “Increasing Participation of Native Hawaiians and Pacific Islanders in STEM: a workshop focused on removing barriers to participation” was held June 1-2, 2016 in Honolulu, HI to identify barriers to participation in STEM disciplines (specifically biosciences and environmental science) among Native Hawaiians and Pacific Islanders. A number of barriers to STEM access were identified in the report[1] for Native Americans and Pacific Islanders in addition to several recommendations for addressing them.
  - A workshop titled, “Pan-REU PI Workshop: Leveraging Excellence Through Collaboration Across REU Programs” was held April 28-30, 2016 in Arlington, VA. The purpose was to inform the Research Experiences for Undergraduates (REU) program officers through the exchange of best practices in different disciplines. This award was co-funded by all NSF Directorates/Offices offering REU Sites, and each discipline was represented at the meeting. The workshop report[2] made several specific recommendations, but emphasized the need for the creation of a pan REU leadership team to strengthen the pan REU community.

Committees of Visitors (COV):

- In FY 2016, BIO held one COV in DBI. The COV convened September 13-15, 2016, at NSF and reviewed division operations and the programmatic portfolio for the three-year period spanning FY 2013-FY 2015. Overall, the COV considered DBI to be on positive trajectory. The COV commended DBI on the improved structure and processes for managing the centers portfolio and these large and mid-scale investments on behalf of BIO. The COV had recommendations for enhancing future operations of DBI: increasing multi-way communication both within DBI and between DBI and other parts of BIO in order to maximize the research impacts of infrastructure investments made by DBI; leverage the expertise the human resources cluster to strengthen efforts for broadening participation across other programs, centers and facilities managed by the division; and make better use

[1] Hadfield, M.G., Kerr, J.Q., Hess, D.J., Smith, C.M., and Marker, N.L. (2016). Recognizing and removing barriers to STEM careers for Native Hawaiians and Pacific Islanders: report on a workshop at the University of Hawaii at Mānoa. Retrieved from www.pbrc.hawaii.edu/stem/Final%20Draft%209-27-16.pdf

[2] NSF Pan REU PI Workshop. (2016). Retrieved from www.cpaess.ucar.edu/sites/default/files/meetings/2016/documents/2016PanREUPIWorkshopReport_Final.pdf

of program officer comments for highly rated proposals that are not recommended for an award. DBI is incorporating these recommendations in its future planning activities.

- In FY 2018, BIO is planning to hold COVs for MCB and IOS.

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

Number of People Involved in BIO Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	3,701	-	3,500
Other Professionals	1,445	-	1,300
Postdoctoral Associates	1,390	-	1,200
Graduate Students	2,768	-	2,600
Undergraduate Students	5,921	-	5,300
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	**15,225**	**-**	**13,900**

DIVISION OF MOLECULAR & CELLULAR BIOSCIENCES (MCB) $123,210,000 -$12,250,000 / -9.0%

MCB Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$135.46**	**-**	**$123.21**	**-$12.25**	**-9.0%**
Research	**132.76**	**-**	**121.37**	**-11.39**	**-8.6%**
CAREER	16.04	-	14.39	-1.65	-10.3%
Education	**2.70**	**-**	**1.84**	**-0.86**	**-31.9%**

MCB supports fundamental interdisciplinary research to uncover the basic principles that describe how information content in cells guides expression of cellular characteristics and is maintained and transmitted to the next generation; how material and energy are taken up, transformed, and flow through biological systems; and how biological molecules assemble into complex structures and compartments with varied functions contribute to the processes required for life. Research at the molecular and cellular scales provides the basis for understanding normal cell processes and healthy cell function. This understanding enables the development of design rules for engineering molecules and cells that contribute to the discovery and biomanufacturing of new drugs to further disease treatment or production of new commercial chemicals.

MCB supports activities in URoL, including basic research to explore origins of life; determine the minimum set of protein and nucleic acid sequences and structures that can sustain life; examine mechanisms of adaptation and homeostasis/robustness of biological systems; identify the repertoire of gene expression that determines the relationship between genotype and phenotype; and develop new theoretical concepts that illuminate 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 utilizes models accompanied by experimental systems in which quantitative measures allow theories to be tested, refined, and validated. MCB gives high priority to interdisciplinary research projects at the interfaces between biology and other research Directorates.

Synthetic Biology in MCB focuses on elucidating normal cellular function by building simple biological systems. The expectation within the division, in partnership with Engineering, is that these forays into designing and building lay the groundwork for complex engineered systems that have practical applications.

Investments in research in plant science at the molecular and cellular scales are part of the MCB strategy to contribute to food security research. Important outcomes of research in systems and synthetic biology and molecular biophysics have led to a greater understanding of photosynthesis, the design of strategies to move nitrogen fixation into photosynthetic organisms (decreasing dependence on fertilizer use), and systems level approaches to understanding drought tolerance in plants.

In general, 65 percent of the MCB portfolio is available for new research grants. The remaining 35 percent supports research and education grants made in prior years.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

Research funding decreases -$11.39 million to a total of $121.37 million.

- Support for CAREER awards decreases $1.65 million to a total of $14.39 million in FY 2018.
- Interdisciplinary research that results in connections across research disciplines contributing to URoL remains a priority for MCB. This support will foster foundational research activities that employ interdisciplinary, quantitative, and theory-based approaches to understand the function and evolution of living systems.
  - Funding for small center scale activities with the Division of Physics (PHY) through the Physics Frontiers Program ($2.40 million), and DMS through a joint public private partnership with the Simons Foundation ($600,000) are hallmarks of these investments in FY 2018.
  - Support will be provided for the URoL emphasis through research at the interface of biology and quantitative and predictive sciences to yield insights into the fundamental molecular and cellular principles of life that provide the foundation for all of biology.
  - Investments in synthetic biology will be aimed at supporting and developing new technologies through a foundational understanding of basic biology such as the Clustered Regularly Interspaced Short Palindromic Repeats (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.
  - Efforts to understand how large biopolymer (proteins, DNA, RNA) sequence gives rise to its structure, self-assembly into larger macromolecular complexes such as ribosomes or chromatin, and how sequence and structure gives rise to function of these macromolecular machines that govern all biological processes in living systems will be continued.
  - MCB will 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.

Education

- FY 2018 investments in REU decrease $890,000 to a total of $1.71 million and Research Experiences for Teachers (RET) increase $20,000 to a total of $130,000.
- MCB continues support of award supplements to enable graduate students to explore career options that reflect the changing workforce needs and employment opportunities in the Nation, including participating in internships in the public and private sectors, attending courses focused on career development, and/or obtaining additional training in specialized areas such as quantitative/computational skills.
- MCB continues to invest in activities to broaden participation of diverse people in STEM fields, through support of RCNs, supplements, and career development activities through professional societies.

DIVISION OF INTEGRATIVE ORGANISMAL SYSTEMS (IOS) $111,200,000
-$103,010,000 / -48.1%

IOS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$214.21**	**-**	**$111.20**	**-$103.01**	**-48.1%**
Research	**186.88**	**-**	**108.57**	**-78.31**	**-41.9%**
CAREER	14.78	-	9.25	-5.53	-37.4%
Education	**4.46**	**-**	**2.63**	**-1.83**	**-41.0%**
Infrastructure	**22.87**	**-**	**-**	**-22.87**	**-100.0%**
Research Resources	22.87	-	-	-22.87	-100.0%

IOS supports research at the level of organisms, at the meso-scale of biological organization, between molecular/cellular and populations/ecosystems. Research and education support is 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 these processes 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, URoL.

IOS science uses evolutionary principles and comparative approaches to develop predictive theories about the regulatory architecture of gene networks and metabolic pathways. IOS encourages synthetic and interdisciplinary approaches and development of new tools. These approaches span computational, mathematical, and organism levels of inquiry and analysis. IOS-supported research affords new understanding of how a wide diversity of organisms respond and adapt to change in order to improve our understanding of the reciprocal interactions between the biological and physical worlds.

Within IOS, 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.

In general, 62 percent of the IOS portfolio is available for new research grants. The remaining 38 percent supports research and education grants made in prior years.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

<u>Research</u>
Research funding decreases $78.31 million to a total of $108.57 million.

- Support for CAREER awards decreases $5.53 million to a total of $9.25 million in FY 2018.
- Funding for the Plant Genome Research Program (PGRP) (-$67.41 million to a total of zero) will move from IOS to EF in FY 2018 to facilitate its role as a central, cross-divisional investment contributing to URoL.

- Support for the Enabling Discovery through Genomic Tools (EDGE) activity in FY 2018 is $6.0 million. URoL 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 the connection between genomes and resulting phenomes. Through EDGE, IOS will support research directed towards developing and disseminating tools as well as methods for enabling emerging model organisms through genomic manipulations that can directly test the relationship of traits to specific genes.
- IOS will continue its collaboration with the National Institutes of Food and Agriculture (NIFA), of the United States Department of Agriculture (USDA), to support research in the area of Plant Biotic Interactions (PBI). Through this collaboration, IOS and NIFA leverage the integration of activities across the spectrum of basic science supported by NSF and the agricultural research supported by NIFA in areas including phytobiomes, plant pathogens, and plant defenses.
- Support for microbe-organism studies across multiple programs will continue. The Symbiosis, Defense and Self-Recognition (SDS) program supports research ($4.0 million) in animal-microbial relationships and the interactions between microbes and protozoa. The PBI program will support research ($5.0 million) on plant-microbe interactions.
- IOS will invest in basic neuroscience research directed towards understanding the development, modification, and activity of the healthy brain during complex natural behaviors. While a significant proportion of BIO's activities related to the BRAIN Initiative will be funded through EF, IOS' investment in neuroscience will support the Understanding the Brain activity, in collaboration with other partners across BIO and NSF. In FY 2018 these activities will focus on opportunities for large-scale data integration, data re-use, and synthesis extending theory.

Education

- PGRP investments (-$2.45 million to a total of zero) in postdoctoral research fellowships are moved from IOS to EF in FY 2018
- FY 2018 investments in REU increase $360,000 to a total of $2.14 million and RET increase $260,000 to a total of $490,000.

Infrastructure

- PGRP investments (-$22.87 million to a total of zero) in research resources are moved from IOS to EF in FY 2018 to facilitate its role as a central, cross-divisional investment contributing to URoL.

DIVISION OF ENVIRONMENTAL BIOLOGY (DEB) $130,780,000

-$13,180,000 / -9.2%

DEB Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$143.96**	**-**	**$130.78**	**-$13.18**	**-9.2%**
Research	**141.38**	**-**	**128.76**	**-12.62**	**-8.9%**
CAREER	7.79	-	3.86	-3.93	-50.5%
Education	**2.42**	**-**	**2.02**	**-0.40**	**-16.5%**
Infrastructure	**0.16**	**-**	**-**	**-0.16**	**-100.0%**

DEB supports fundamental research on earth's biodiversity and the ecological and evolutionary processes that explain the origin and maintenance of genetic variation in nature, including its history and patterns of speciation and extinction. DEB supports activities in URoL, including research that advances understanding of the functional importance of biodiversity to ecological and ecosystem processes occurring over short and long temporal and spatial scales. The discoveries from this research are the basis for management of the nation's biological resources, including agricultural and native systems, and prediction of changes in species abundance and ecosystem services over time.

DEB funded research provides the data, knowledge, and modeling capability to forecast the spread of infectious diseases and of invasive species, and their impacts on wild, managed, and agricultural systems. Models developed from biodiversity and ecological research are used to predict drivers environmental change that impact society and enhance the nation's ability to strategically prepare for environmental threats, and field defense capabilities that are resilient and adaptive.

In general, 66 percent of the DEB portfolio is available for new research grants. The remaining 34 percent supports research and education grants made in prior years.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

Research funding decreases $12.62 million to a total of $128.76 million.

- DEB will prioritize basic research that focuses on science related to URoL at scales of biological organization spanning local populations of organisms to regional and continental scale ecosystems. Emphasis will be on the integration of ecology and evolution, and sustaining support for development and testing of theory that transcends disciplinary boundaries to understand biological phenomena that cannot be explained by either discipline alone.
- Support for the Dimensions of Biodiversity program will be sustained at $11.0 million. Research projects funded by this program provide foundational knowledge on the maintenance and functional properties of the diversity of life on earth. This research informs management and conservation of genetic and other biological resources in the context of dynamic ecosystems.
- Support for the Long Term Ecological Research (LTER) program will decrease $1.40 million to a total of $20.30 million, to sustain a national network of sites conducting research on the structure and function of the nation's ecosystems. The LTER sites encompass a large range of ecosystem types in the

United States, including deserts, mountains, lakes, swamps, prairies, coastal regions, tropical, temperate, and boreal forests, and arctic tundra. Research supported by this program contributes to our understanding of ecosystem services and environmental sustainability.
- Support for the Ecology and Evolution of Infectious Disease program will be sustained at $6.0 million. This program, which is a partnership with the National Institutes of Health and USDA, funds research to advance basic understanding and develop predictive models for disease risk, including threats to humans, wildlife, farm animals, crop, and native plants.
- Encouragement and support for research using NEON data, samples, and resources to address macro-scale environmental questions in the DEB core programs will continue in anticipation of the completion of NEON construction.

Education
- FY 2018 investments in REU decrease $350,000 to a total of $1.78 million and RET decrease $50,000 to a total of $240,000.

DIVISION OF BIOLOGICAL INFRASTRUCTURE (DBI) $169,610,000

+$25,000,000 / 17.3%

DBI Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$144.61**	**-**	**$169.61**	**$25.00**	**17.3%**
Research	**40.51**	**-**	**30.68**	**-9.83**	**-24.3%**
CAREER	4.41	-	5.81	1.40	31.7%
Centers Funding (total)	33.76	-	21.00	-12.76	-37.8%
Centers for Analysis & Synthesis	18.40	-	6.00	-12.40	-67.4%
Nanoscale Science & Engineering Centers	5.36	-	-	-5.36	-100.0%
STC: BEACON	5.00	-	5.00	-	-
STC: XFel	5.00	-	5.00	-	-
STC: CCC	-	-	5.00	5.00	N/A
Education	**28.59**	**-**	**19.64**	**-8.95**	**-31.3%**
Infrastructure	**75.51**	**-**	**119.29**	**43.78**	**58.0%**
CHESS	5.00	-	4.00	-1.00	-20.0%
NEON	-	-	65.00	65.00	N/A
NNCI	0.35	-	0.35	-	-
Research Resources	70.16	-	49.94	-20.22	-28.8%

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 cyberinfrastructure, instrumentation, improvements to biological research collections, living stock collections, field stations, and marine labs. In addition, DBI supports the development of human capital through undergraduate 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. 21st century biological research is evolving into a transdisciplinary and data-driven science that requires a range of infrastructure and a highly trained workforce. DBI funds activities on a scale that ranges from molecular to continental and addresses processes involving the reciprocal interactions between genomes, phenomes, and the environment. These projects, which will be instrumental for URoL, include high-throughput phenotyping, modeling microbial species interactions, biodiversity and ecological forecasting, and mapping the brain connectome.

In FY 2018, DBI will utilize the outcomes of two program evaluations conducted in FY 2017 to leverage the importance of biological research collections in the context of research activities across the directorate and to better serve the instrumentation needs of the biological research community. A priority will be research resources to support innovation and enhance capacity in order to address long term resource needs and the development of a robust STEM pipeline. In particular, a focus on developing new tools and supporting cyberinfrastructure to meet the data integration challenges emerging as part of ecological forecasting associated with NEON or predictive relationships from genomic, environmental, and phenotypic characteristics of biological systems are areas that will be addressed by DBI programs.

In general, 34 percent of the DBI portfolio is available for new research grants and 66 percent funds continuing grants made in previous years.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

Research funding decreases $9.83 million to a total of $30.68 million.

- Support for centers will decrease $12.76 million to a total of $21.0 million.
  - The Centers for Analysis and Synthesis, CyVerse (formerly iPlant) and the National Institute for Mathematical and Biological Synthesis (NIMBioS), as well as the Nanoscale Science and Engineering Centers, Centers for the Environmental Implications of Nanotechnology (CEIN)-UCLA and CEIN-Duke, will have completed their respective funding cycles in FY 2017.
  - Funding for the STCs BEACON, XFEL, and CCC will continue through FY 2018; XFEL is expected to be renewed at the FY 2016 Actual level.
  - Funding for SESync, a Center for Analysis and Synthesis, will continue at current funding levels.
- While the majority of BIO's UtB investment is funded through EF, a significant component 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. The awards made through the new NeuroNex solicitation will be managed in DBI with support from IOS.

Education

- IUSE (-$240,000 to a total of $2.50 million) is centralized within DBI through the RCN-UBE program.
- FY 2018 funding for the Postdoctoral Research Fellowships in Biology program is decreased $3.20 million to a total of $4.0 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.
- DBI will maintain a contribution (no change; total of $1.40 million) to NSF INCLUDES to promote the advancement of underrepresented groups in STEM.
- FY 2018 investments in REU decrease $2.52 million to a total of $11.09 million and RET decrease $30,000 to a total of $30,000.

Infrastructure

- Two facilities will receive continued funding: CHESS (-$1.0 million to a total of $4.0 million) and NNCI (no change; total of $350,000).
- In FY 2018, NEON O&M funding (+$65.0 million to a total of $65.0 million) moves from EF to DBI in accordance with the shift in program management and oversight that occurred in FY 2017. For more detailed information on NEON, see the MREFC chapter.
- Research resources decrease $20.22 million to a total of $49.94 million.
  - Approximately $14 million of the decrease is attributed to reduced funding for BIO's research resource programs as assessments, begun in FY 2017, on the effectiveness of these programs are completed and their future directions are determined.
  - Emphases within research resources will be related to the BIO emphasis area, URoL. This will include support for multidisciplinary imaging, digitization of biological specimens, cyberinfrastructure in support of synthetic biology, and high performance computing resources and tools necessary to address priority research initiatives under URoL, 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 of different types of data across spatial and temporal scales and for the large neuroscience investments being made through NeuroNex.

DIVISION OF EMERGING FRONTIERS (EF) $137,310,000
+$51,780,000 / 60.5%

EF Funding
(Dollars in Millions)

	FY 2016 Actual[1]	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$85.53**	**-**	**$137.31**	**$51.78**	**60.5%**
Research	**51.44**	**-**	**112.26**	**60.82**	**118.2%**
CAREER	2.66	-	1.76	-0.90	-33.8%
Education	**1.12**	**-**	**3.80**	**2.68**	**239.5%**
Infrastructure	**32.97**	**-**	**21.25**	**-11.72**	**-35.6%**
NEON	32.97	-	-	-32.97	-100.0%
Research Resources	-	-	21.25	21.25	N/A

[1] In FY 2016, $20.0 was transferred to the MREFC account for increased NEON construction costs. Including this transfer, EF's total funding in FY 2016 was $105.53 million. FY 2018 Request funding for EF compared to EF's initial FY 2016 budget is a increase of $31.78 million or 30.1 percent.

EF identifies, incubates, and supports infrastructure and research areas that transcend scientific disciplines and/or advance conceptual foundations across all of biology. 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). New programs and priority areas, especially those that are cross-cutting, typically begin development in EF and then move to other BIO divisions to become part of the disciplinary knowledge base. Examples include the Advanced Digitization of Biodiversity Collections (ADBC) program which has now transitioned into DBI. In FY 2018, EF will provide support for cross-cutting core activities that contribute to URoL, an emphasis area that began in FY 2017.

The Plant Genome Research Program (PGRP) will transition to EF in FY 2018. 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-energy, development of sources of novel bio-based materials, and adaptation of plants to novel environments. 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.

In general, 46 percent of the EF portfolio is available for new research grants. The remaining 54 percent supports research, education, and infrastructure grants made in prior years.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research
Research funding increases $60.82 million to a total of $112.26 million.

- PGRP funding (+$57.41 million to a total of $67.41 million) will move from IOS to EF in FY 2018 to reflect this program's central role in developing basic knowledge of the structures and functions of plant genomes and translation of this knowledge into a comprehensive understanding of all aspects of economically important plants and plant processes of potential economic value.
- Support for neuroscience activities in EF and will be focused on the NeuroNex program.

- Support ($3.0 million) for high performance computing resources and tools necessary to address cross-directorate priority research initiatives under URoL will move from DBI to EF in FY 2018.
- Funding for URoL activities will include support for tools, technologies and modeling approaches to understanding the flow of information from genotype to phenotype across scales, synthetic biology, origins of life, and developing biological theory as a framework for URoL.

Education

- Education investments in EF, through PGRP, will provide support (+$3.80 million to a total of $3.80 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 USDA, Agricultural Research Service (ARS).

Infrastructure

- In FY 2018, NEON O&M funding (-$32.97 million to zero) moves from EF to DBI in accordance with the shift in program management and oversight that occurred in FY 2017. For more detailed information on NEON, see the MREFC chapter.
- With the shift in funding from IOS to EF, research resources (+$21.25 million to a total of $21.25 million) will support investments essential to PGRP, including tools for high-throughput analysis of agriculturally important plant phenotypes under field conditions are maintained.

DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) $838,920,000 -$96,280,000 / -10.3%

CISE Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Office of Advanced Cyberinfrastructure (OAC)	$222.19	-	$199.31	-$22.88	-10.3%
Computing and Communication Foundations (CCF)	194.13	-	174.14	-19.99	-10.3%
Computer and Network Systems (CNS)	230.99	-	207.21	-23.78	-10.3%
Information and Intelligent Systems (IIS)	194.80	-	174.75	-20.05	-10.3%
Information Technology Research (ITR)	93.09	-	83.51	-9.58	-10.3%
Total	**$935.20**	**-**	**$838.92**	**-$96.28**	**-10.3%**

About CISE

Advances in information technology (IT) over the past two decades have proven to be key drivers of U.S. economic competitiveness. Essentially all practical applications of today's IT are based on ideas and concepts that emerged from investments in fundamental computing research, many of them funded by NSF and CISE.[1] Fundamental ideas and concepts advanced through computing research have enabled innovative products and applications that now permeate many aspects of daily life, including personal communications, energy, transportation, health care, advanced manufacturing, national and homeland security, disaster preparedness and response, education and workforce development, public and private organizational effectiveness and efficiency, and discovery and innovation at the frontiers of all areas of scientific and engineering research. Maintaining U.S. leadership in IT and its applications, including in intelligent infrastructure, augmented and virtual reality, quantum computing, and research cyberinfrastructure for all domains, will require sustained investment. Indeed, NSF and CISE must continue to play a central and leadership role in improving the Nation's economic outlook and advancing a highly-trained, technologically astute workforce.

Specifically, 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 subfields 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 executes its mission through its Divisions of Computing and Communication Foundations (CCF), Computer and Network Systems (CNS), Information and Intelligent Systems (IIS), and Information and Technology Research (ITR), and the Office of Advanced Cyberinfrastructure (OAC).

CISE's FY 2018 Budget Request is shaped by the following NSF-wide priorities: Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS); Harnessing the Data Revolution (HDR) Big Idea; National

[1] www.nap.edu/catalog.php?record_id=13427

Strategic Computing Initiative (NSCI); NSF Innovation Corps (NSF I-Corps™); NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES); Secure and Trustworthy Cyberspace (SaTC); Smart and Connected Communities (S&CC); and Understanding the Brain (UtB). In addition to the HDR Big Idea, CISE will also actively participate in several other Big Ideas in collaboration with all NSF directorates and offices, particularly Work at the Human-Technology Frontier (W-HTF), Quantum Leap, Navigating the New Arctic, Rules of Life, Convergence, and Mid-Scale Research Infrastructure. Progress in foundational research, research infrastructure, and education in these areas is vital to address key national challenges, spur innovation, increase productivity, secure critical infrastructure, improve data analysis and sharing, and develop the next generation of computing and computational scientists and engineers.

In addition, CISE continues to provide leadership for the multi-agency National Science and Technology Council (NSTC) Committee on Technology (COT) Subcommittee on Networking and Information Technology Research and Development (NITRD). The NITRD Subcommittee is co-chaired by the CISE Assistant Director. All research, education, and research infrastructure projects supported by CISE enrich the agency's NITRD portfolio.

CISE provides about 83 percent of the federal funding for basic research at U.S. academic institutions in computer science.

Major Investments

CISE Major Investments

(Dollars in Millions)

				Change Over FY 2016 Actual	
Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Amount	Percent
CAREER	$45.20	-	$37.30	-$7.90	-17.5%
CEMMSS	91.93	-	72.70	-19.23	-20.9%
Advanced Manufacturing	*43.25*	-	*37.00*	*-6.25*	*-14.5%*
CIF21	87.50	-	-	-87.50	-100.0%
HDR	-	-	50.00	50.00	N/A
INFEWS	8.00	-	-	-8.00	-100.0%
IUSE	1.98	-	2.00	0.02	1.0%
NRT	7.69	-	3.00	-4.69	-61.0%
NSCI*	-	-	97.00	97.00	N/A
NSF I-Corps™	11.71	-	9.65	-2.06	-17.6%
NSF INCLUDES	1.72	-	1.78	0.06	3.5%
R&R	5.98	-	-	-5.98	-100.0%
SaTC	70.90	-	65.50	-5.40	-7.6%
S&CC	13.50	-	16.50	3.00	22.2%
Understanding the Brain	30.60	-	22.15	-8.45	-27.6%
BRAIN Initiative	9.80	-	9.50	-0.30	-3.1%

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

*This includes $60 million in FY 2018 as part of OAC's HPC investment for a leadership-class computing resource (see HPC Appendix for more information).

All funding decreases/increases represent changes over the FY 2016 Actual.

- Faculty Early-Career Development Program (CAREER) (-$7.90 million to a total of $37.30 million): CISE will continue to invest in CAREER, which supports 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 (-$19.23 million to a total of $72.70 million): CISE will continue to lead CEMMSS, in partnership with the Directorate for Biological Sciences (BIO), Directorate for Education and Human Resources (EHR), Directorate for Engineering (ENG), and Directorate for Mathematical and Physical Sciences (MPS), aiming 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 such systems in their full complexity and dynamics; and develop a smart systems technology framework spanning robotic and cyber-physical systems. As part of CEMMSS, CISE will continue to lead the Cyber-Physical Systems (CPS) and National Robotics Initiative (NRI) programs. These investments will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated.

- Advanced Manufacturing (-$6.25 million to a total of $37.0 million): As part of CEMMSS, CISE, in partnership with ENG and MPS, will continue to 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.

- Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) (-$87.50 million to a total of zero): CISE investments in CIF21 will transition to HDR and NSCI in FY 2018.

- HDR (+$50.0 million to a total of $50.0 million): CISE will lead HDR in partnership with all other NSF directorates and offices, continuing the visioning and planning activities that have already begun.[2] HDR will engage NSF's research and education community in the pursuit of fundamental research in data science and engineering, the development of a cohesive, federated, national-scale approach to research data infrastructure, and the development of a 21st-century data-capable workforce. CISE, together with MPS, will continue the initial HDR investment in Transdisciplinary Research in Principles of Data Science (TRIPODS), bringing together the statistics, mathematics, and theoretical computer science communities to develop the theoretical foundations of data science through integrated research and training activities. In addition to these forward-looking investments aimed at building the foundation for future HDR activities, HDR will also encompass NSF's existing data-related research, research infrastructure, and education portfolio that is transitioning from CIF21, including Critical Techniques, Technologies and Methodologies for Advancing Foundations and Applications of Big Data Science (BIGDATA); Data Infrastructure Building Blocks (DIBBs); EarthCube; and Resource Implementations for Data Intensive Research in Social, Behavioral, and Economic Sciences (RIDIR). As part of HDR, CISE will also collaborate with other NSF directorates and offices on new approaches to community data governance and research data lifecycles in alignment with NSF's *Public Access Plan*.

[2] Dear Colleague Letter: Growing Convergence Research at NSF (NSF 17-065), www.nsf.gov/pubs/2017/nsf17065/nsf17065.jsp.

- Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) (-$8.0 million to a total of zero): CISE will continue to support research related to this area through investments in CEMMSS, notably CPS, and S&CC.

- Improving Undergraduate STEM Education (IUSE) (+$20,000 to a total of $2.0 million): CISE will continue to invest in IUSE, with a focus on novel approaches for CS+X, enabling the diffusion of the fundamentals of computational thinking and computer science across a broad array of other disciplines at the undergraduate level.

- NSF Research Traineeships (NRT) (-$4.69 million to a total of $3.0 million: CISE will continue to invest in NRT, supporting STEM graduate students in interdisciplinary areas of national priority, as well as the development of bold, new, potentially transformative, and scalable models for STEM graduate training.

- NSCI (+$97.0 million to a total of $97.0 million): CISE, through OAC, will co-lead NSCI with MPS and in partnership with other NSF directorates and will represent NSF in its leadership role for NSCI across the federal government. The goal of NSCI is to advance national leadership in High-Performance Computing (HPC) and maximize the benefits of HPC for scientific discovery and economic competitiveness. Under NSCI, CISE will support research advances in new computing technologies, architectures, and platforms for the future, as well as the development and deployment of advanced HPC systems, including maximizing their benefits through deep integration of HPC cyberinfrastructure with science and engineering research. This deep and agile engagement will be pursued along a number of key fronts: 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, programmability, networking technology, accessibility, workflow, and workforce development.

- NSF I-Corps™ (-$2.06 million to a total of $9.65 million): CISE will continue to invest in I-Corps™ Nodes, Sites, and Teams 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 investments in NSF I-Corps™ 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 (+$60,000 to a total of $1.78 million): CISE will continue to invest 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.

- Risk and Resilience (R&R) (-$5.98 million to a total of zero): CISE will continue to support research related to this area through investments in CEMMSS, notably CPS, and S&CC.

- SaTC (-$5.40 million to a total of $65.50 million): CISE will continue to lead SaTC, in partnership with EHR, ENG, MPS, and the Directorate for Social, Behavioral, and Economic Sciences (SBE), aligning cybersecurity investments with the federal cybersecurity R&D strategy. SaTC aims to support the foundational research necessary to ensure society's ubiquitous computing and communication systems are resistant to cyber-attacks and associated vulnerabilities, while enabling and preserving privacy and trust. As part of this investment, CISE will continue collaborating with EHR to support a growing pipeline of cybersecurity researchers and educators, and to develop a citizenry that understands the security and privacy of the digital systems on which it increasingly depends.

- S&CC (+$3.0 million to a total of $16.50 million): CISE will continue to lead S&CC, in partnership with EHR, ENG, the Directorate for Geosciences (GEO), and SBE, pursuing interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities and that lead to enhanced quality of life for residents. CISE investments 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/disaster preparedness and response.

- UtB (-$8.45 million to a total of $22.15 million): CISE will continue to invest in 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 brain knowledge across scales and disciplines; and innovative neurotechnologies to monitor and further brain function. This research will aim to accelerate the formulation of an integrative, quantitative, and predictive theory of brain function.

CISE Funding for Centers Programs and Facilities

CISE Funding for Centers Programs

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Centers Programs	**$10.00**	**-**	**$10.00**	**-**	**-**
STC: Center for the Science of Information	5.00	-	5.00	-	-
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	5.00	-	5.00	-	-

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

CISE Funding for Facilities

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Facilities	**$0.60**	**-**	**$0.60**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (NNCI) Program (CCF)	0.60	-	0.60	-	-

For detailed information on individual facilities, see the Facilities and the Major Research Equipment and Facilities Construction chapters.

Funding Profile

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

In FY 2018, the number of research grant proposals is expected to increase by 3.0 percent compared to the FY 2016 Actual Estimate, with CISE anticipating awarding approximately 1,450 research grants in FY 2018. Average annualized award size and average award duration are expected to remain relatively stable between the FY 2016 Actual Estimate and FY 2018 Estimate.

Funding for research infrastructure represents 18.8 percent of the CISE Request. Most of CISE's research infrastructure support is for HPC (see Appendix A for more information on the HPC portfolio).

CISE Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	8,301	-	8,550
Number of New Awards	1,919	-	1,720
Funding Rate	23%	-	20%
Statistics for Research Grants:			
Number of Research Grant Proposals	7,909	-	8,150
Number of Research Grants	1,622	-	1,450
Funding Rate	21%	-	18%
Median Annualized Award Size	$156,309	-	$160,000
Average Annualized Award Size	$203,144	-	$200,000
Average Award Duration, in years	2.8	-	3.0

Program Monitoring and Evaluation

Committees of Visitors (COV):

- 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.
- OAC plans to hold a COV in FY 2018.

Program Evaluations:

- In FY 2012, the Science and Technology Policy Institute (STPI) conducted program evaluation feasibility studies for the CEMMSS and SaTC investments. These feasibility studies provided methods for examining baseline portfolio investments and identifying metrics to measure progress toward program goals. They were part of a broader effort to develop a plan for impact assessments, particularly for the SaTC investment. STPI identified baseline evaluation metrics in FY 2013-FY 2015, and completed the evaluation feasibility studies for CEMMSS and SaTC in FY 2016.
- Evaluation is a key part of CISE's education programs. Both STEM + Computing Partnerships (STEM+C) and Computer Science for All (CSforAll) projects managed by CISE include rigorous research and evaluation plans designed to guide project progress and measure project impacts. Additionally, CISE tasked STPI to conduct an evaluation feasibility study for STEM+C, and the

Education Development Center, Inc. (EDC) to develop a program evaluation instrument for legacy CSforAll (CS 10K) projects. The first program evaluation of the CS 10K projects is currently under way.

Reports:

- In 2008, CISE funded the Computer Science and Telecommunications Board (CSTB) within the National Academy of Sciences, Engineering, and Medicine 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,*[3] 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.[4] A more recent CSTB study, *Continuing Innovation in Information Technology: A Workshop* (described below), employed this report's framework.
- In FY 2012, a CSTB study, *The Future of Computing Performance: Game Over or Next Level?,*[5] together with a white paper from the CISE-funded Computing Community Consortium (CCC), *21st Century Computer Architecture,*[6] outlined the need for advances in computer architecture research, leading to the development of the Exploiting Parallelism and Scalability (XPS) program in FY 2013. In FY 2018, CISE will continue to invest in advanced computer architecture research through the Scalable Parallelism in the Extreme (SPX) program, leveraging past investments in XPS.
- 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;[7] this led to the development of the NSFFutureCloud program started in FY 2014. In FY 2018, CISE will continue to invest in NSFFutureCloud.
- Since FY 2014, the CCC has led several additional community visioning efforts that have the potential to influence CISE programs in FY 2018:
  - *Computing Visions 2025:*[8] inspired 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.*
  - *Toward a Science of Autonomy for Physical Systems:*[9] offered a series of white papers framing the challenges and opportunities associated with a future of autonomous physical systems across a range of domains including health care, transportation, and disaster response. These white papers have the potential to influence CISE investments in CEMMSS, including in CPS and NRI.
  - *A New Age of Computing and the Brain:* brought together computer and information scientists and engineers and brain scientists to explore opportunities and connections at the intersection of computer and information science and brain science. The resultant workshop report summarizing the key findings has the potential to influence CISE and NSF investments in UtB.[10]
  - *Artificial Intelligence (AI) for Social Good:*[11] furthered the discussion of the benefits of AI to

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

society. Two workshops were held jointly with the Association for the Advancement of Artificial Intelligence (AAAI), exploring the potential use of AI in various areas, including smart and connected communities, health and wellness, and security. The CCC also published a white paper about advances in AI.[12] These efforts have the potential to influence CISE investments in AI.

- *Intelligent Infrastructure:*[13] presented a national research agenda for intelligent infrastructure, or the deep embedding of sensing, computation, and communication capabilities into traditional physical infrastructure such as roads, bridges, railways, and buildings, for the purpose of enhancing efficiency, resiliency, and safety. These white papers, which the CCC produced jointly with the Electrical and Computer Engineering Department Heads Association (ECEDHA), have the potential to influence CISE investments in S&CC.

- Similarly, since FY 2014, CISE has funded several CSTB studies that have the potential to influence CISE programs in FY 2018:
  - *Continuing Innovation in Information Technology: A Workshop:* conducted a public workshop to highlight 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 Information Technology*. The resultant workshop report was published in 2016.[14]
  - *Toward 21st-Century Cyber-Physical Systems Education:* published a report in 2016 on the current and future needs in education for cyber-physical systems (CPS), articulating a vision for a 21st-century CPS-capable U.S. workforce.[15]
  - *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science in 2017-2020:* published a report in 2016 on anticipated priorities and associated tradeoffs for advanced computing in support of NSF-sponsored science and engineering research, yielding recommendations in support of four broad goals: (1) position the United States for continued leadership in science and engineering, (2) ensure that resources meet community needs, (3) aid the scientific community in keeping up with the revolution in computing, and (4) sustain the infrastructure for advanced computing.[16]
  - *Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?:* published a report in 2017 on the interactions between technological, economic, and societal trends, notably how significant advances in IT and automation have profoundly impacted the way work is conducted, and identified open questions and promising research pathways.[17]
  - *Envisioning the Data Science Discipline: The Undergraduate Perspective:*[18] is developing a vision for the emerging discipline of data science at the undergraduate level.
  - *Growth of Computer Science Undergraduate Enrollments:*[19] is examining potential responses to the current large influx of undergraduate students enrolling in computing and computer science courses.

[12] http://cra.org/ccc/wp-content/uploads/sites/2/2015/01/CCC-AI-Systems-2017-FINAL.pdf
[13] http://cra.org/ccc/resources/ccc-led-whitepapers/#infrastructure
[14] https://www.nap.edu/catalog/23393/continuing-innovation-in-information-technology-workshop-report
[15] www.nap.edu/catalog/23686/a-21st-century-cyber-physical-systems-education
[16] www.nap.edu/catalog/21886/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-and-engineering-in-2017-2020
[17] www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[18] http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_175246
[19] http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_171607

Number of People Involved in CISE Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	7,288	-	6,500
Other Professionals	1,238	-	1,100
Postdoctoral Associates	490	-	400
Graduate Students	6,565	-	5,900
Undergraduate Students	2,660	-	2,400
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	18,241	-	16,300

OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC) $199,310,000

-$22,880,000 / -10.3%

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$222.19**	**-**	**$199.31**	**-$22.88**	**-10.3%**
Research	**86.39**	**-**	**76.61**	**-9.78**	**-11.3%**
CAREER	2.04	-	1.80	-0.24	-11.6%
Education	**6.44**	**-**	**5.20**	**-1.24**	**-19.3%**
Infrastructure	**129.35**	**-**	**117.50**	**-11.85**	**-9.2%**
Networking and Computational Resources Infrastructure and Services	129.35	-	117.50	-11.85	-9.2%

OAC supports the exploration, development, deployment, and expert services necessary for world-leading research cyberinfrastructure (CI), which is critical to the advancement of all areas of science and engineering research and education in the 21st century and therefore essential to sustaining U.S. economic competitiveness and national security. In partnership with all NSF directorates and offices as well as other CISE divisions, OAC support to academic institutions encourages a rich and vibrant ecosystem that blends research-specific infrastructure with innovations from the private sector. Specifically, OAC investments include acquisition, integration, coordination, and operations associated with shared data, secure networking, advanced computation, scientific software, and the development of computational and data-enabled science and engineering tools and expertise. OAC also nurtures the computational and data skills and expertise needed to conduct next-generation science and engineering. In order to address complex and multidisciplinary discovery, prediction, and innovation, OAC enables more than 8,000 faculty and researchers to access computational resources and services, along with secure connectivity to major international facilities and scientific instruments. Ultimately, OAC promotes secure CI interoperability, sharing, and collaborations among academic research infrastructure groups, other federal agencies and international research funding agencies, and the private sector.

In general, about 42 percent of the OAC portfolio is available for new grants and 58 percent is available for continuing grants.

Approximately 55 percent of OAC's budget is used to support individuals and small groups of researchers in pilot, prototype, and innovative multidisciplinary projects. The remaining 45 percent of the budget goes toward the support of larger cyberinfrastructure consortia, including Petascale Computing, Innovative High-Performance Computing (HPC), and eXtreme Digital (XD) shared services. Collectively, these larger-scale programs complement and connect both smaller NSF-supported as well as university-supported CI as part of an integrated, national research infrastructure ecosystem.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

<u>Research</u>

- OAC will continue to invest in early-career researchers through CAREER (-$240,000 to a total of $1.80 million).
- OAC will transition support for CIF21 (-$62.0 million to a total of zero), investing in NSCI (+$26.50

million to a total of $26.50 million) and HDR (+$30.0 million to a total of $30.0 million). Together with MPS, OAC will co-lead the NSF-wide NSCI activity and will represent NSF in its leadership role for NSCI across the federal government. OAC research investments in NSCI will emphasize future HPC systems beyond the limits of current semiconductor technology, as well as emerging infrastructure, including quantum technologies, for all areas of science and engineering. In concert with investments by other NSF directorates/offices, OAC investments in NSCI will also support novel scientific software architectures that are resilient, reusable, and enduring yet agile to accelerate robust research. These OAC research activities in NSCI are complemented by Advanced Computational Infrastructure activities, as noted below. In coordination with NSF research priorities and CI investments by other directorates/offices, OAC investments in HDR will recognize the enormous potential of data science to all fields of science and engineering. OAC will emphasize support for innovative, reusable, and sustainable data science tools and data sharing infrastructure for all research communities. OAC will also collaborate with other NSF directorates/offices on new approaches to community data governance and research data lifecycles in alignment with NSF's *Public Access Plan*.

- OAC will continue to invest in UtB (-$5.0 million to a total of $1.0 million) to support exploration of research infrastructure for neuroscience in collaboration with BIO and MPS and in alignment with HDR.
- OAC will discontinue support for INFEWS (-$3.0 million to a total of zero) and R&R (-$2.48 million to a total of zero), but will continue to support research related to these areas through investments in other programs.

Education

- OAC will invest in CyberTraining (+$3.50 million to a total of $3.50 million) to prepare, nurture, and grow the national scientific workforce for creating, utilizing, and supporting advanced CI that enables cutting-edge science and engineering and contributes to the Nation's overall economic competitiveness and security.
- OAC will continue to invest in CSforAll (level at $500,000), which seeks to enable rigorous and engaging computer science education in schools across the Nation.
- OAC will continue to invest in Research Experiences for Undergraduates (REU) sites and supplements (-$1.26 million to a total of $1.20 million).
- OAC will discontinue support for NRT (-$3.0 million to a total of zero).

Infrastructure

- OAC will continue to support Advanced Computational Infrastructure (-$7.15 million to a total of $89.50 million), to enable research priorities and advances beyond the grasp of individual institutions OAC investments will be in alignment with NSCI and the recommendations of a recent National Academies study, *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering 2017-2021*. As part of NSCI, $60.0 million of OAC's HPC investment will be for a new leadership-class computing resource (see Appendix A for more information on the HPC portfolio).
- OAC will continue to invest in SaTC (-$1.50 million to a total of $2.50 million), leading the Transition to Practice (TTP) Option, which explores new approaches for adopting advances in security for research CI, including emphasizing interagency and cross-sector collaborations.

DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS (CCF) $174,140,000 -$19,990,000 / -10.3%

CCF Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$194.13**	**-**	**$174.14**	**-$19.99**	**-10.3%**
Research	**183.75**	**-**	**163.54**	**-20.21**	**-11.0%**
CAREER	15.82	-	12.10	-3.72	-23.5%
Centers Funding (total)	8.00	-	8.00	-	-
STC: Center for the Science of Information	5.00	-	5.00	-	-
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	3.00	-	3.00	-	-
Education	**9.78**	**-**	**10.00**	**0.22**	**2.2%**
Infrastructure	**0.60**	**-**	**0.60**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.60	-	0.60	-	-

CCF contributes to scientific advancement, economic growth, human health, and national security by laying the foundations of the theory and practice of computing and communication. CCF supports research and education activities that explore the foundations and limits of computation, communication, and information; advance algorithmic knowledge for research areas within and outside computer science; and advance software and hardware 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 that addresses the theoretical underpinnings and enabling technologies for information acquisition, transmission, and processing in communication and information networks, such as sensor, wireless, multimedia, quantum, and biological networks. CCF investments advance the design, verification, evaluation, and utilization of computing hardware and software through new theories, programming languages, and formal methods that focus on achieving performance, correctness, usability, reliability, and scalability. CCF research explores the potential impact of emerging technologies on computation and communication, including nanotechnology, biotechnology, and quantum devices and systems.

In general, 77 percent of the CCF portfolio is available for new research grants and 23 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CCF will continue to invest in early-career researchers through CAREER (-$3.72 million to a total of $12.10 million).
- CCF will continue to support the NSF-wide CEMMSS investment through CPS (-$1.0 million to a total of $4.50 million) and NRI (-$1.50 million to a total of $1.50 million). This investment will emphasize development of new methods for specification and verification of software and hardware systems useful for various sectors including cyber-manufacturing.

- CCF will transition support for CIF21 (-$9.50 million to a total of zero), investing in SPX (-$2.0 million to a total of $4.50 million) as part of NSCI, and BIGDATA (level at $5.0 million) and TRIPODS (+$1.0 million to a total of $1.0 million) as part of HDR. CCF investments in NSCI will pursue foundational research leading to future HPC systems beyond the limits of current semiconductor technology, including addressing the challenges of performance, scalability, programmability, portability, and reliability. CCF investments in NSCI will also support quantum technologies. CCF investments in HDR will pursue research on the foundations of data science, from the generation and collection of data to analytics and decision making; and on foundational techniques that enable computationally-efficient storage and processing of big data, as well as more effective query and analysis from heterogeneous data sources.
- CCF will invest in S&CC (+$1.50 million to a total of $1.50 million), pursuing interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities, leading to enhanced quality of life for residents.
- CCF will continue to invest in UtB (-$750,000 to a total of $7.90 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 to invest in SaTC (-$2.50 million to a total of $11.75 million), supporting research on theories, models, algorithms, architectures, and programming languages for increased security, privacy, and trust, as well as in new cryptographic approaches for hardware assurance.
- CCF will continue to invest in Smart and Connected Health (SCH) (-$2.0 million to a total of $1.0 million), supporting signal processing and control research with application to devices and sensors for person-centered health and wellbeing.
- CCF will continue to invest in two STCs, the Center for the Science of Information at Purdue University (level at $5.0 million) and the Center for Brains, Minds, and Machines: The Science and the Technology of Intelligence at the Massachusetts Institute of Technology (MIT) (level at $3.0 million). The CCF investment in the MIT STC is shared with the IIS and ITR divisions.
- CCF will discontinue support for INFEWS (-$2.50 million to a total of zero) but will continue to support research related to this area through investments in CEMMSS, notably CPS and S&CC.

Education

- CCF will continue to invest in NRT (level at $1.0 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 continue to invest in CSforAll (level at $4.0 million), which seeks to enable rigorous and engaging computer science education in schools across the Nation.
- CCF will continue to invest in REU sites and supplements (+$220,000 to a total of $4.40 million).

Infrastructure

- CCF will continue to invest in the National Nanotechnology Coordinated Infrastructure (NNCI) (level at $600,000), supported primarily by ENG.

DIVISION OF COMPUTER AND NETWORK SYSTEMS (CNS) $207,210,000
-$23,780,000 / -10.3%

CNS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$230.99**	**-**	**$207.21**	**-$23.78**	**-10.3%**
Research	**182.57**	**-**	**166.12**	**-16.45**	**-9.0%**
CAREER	9.60	-	9.60	-	-
Education	**18.43**	**-**	**13.09**	**-5.34**	**-29.0%**
Infrastructure	**29.99**	**-**	**28.00**	**-1.99**	**-6.6%**
Research Resources	29.99	-	28.00	-1.99	-6.6%

CNS contributes to scientific advancement, national security, and societal welfare through research and education activities that advance understanding of the fundamental properties of computer systems and networks. CNS investments produce new insights into the dynamics of complex hardware and software systems, and explore new architectures for future-generation computing and communication infrastructures and services, thereby lowering barriers to innovation and enhancing economic competitiveness. CNS-enabled systems include, but are not limited to, cyber-physical, embedded, distributed, centralized, virtualized, and mobile systems. CNS also provides scientific leadership in cybersecurity, supporting research and education activities to ensure that society's ubiquitous computing and communication infrastructures 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 systems research infrastructure and in the development of the computing workforce of the future.

In general, 67 percent of the CNS portfolio is available for new grants and 33 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CNS will continue to invest in early-career researchers through CAREER (level at $9.60 million).
- CNS will continue to lead SaTC (level at $43.70 million) in partnership with EHR, ENG, MPS, SBE, and the other CISE divisions. CNS will invest in areas of current critical importance, such as network and cloud security, cybereconomics, usability of security and privacy technologies, and assurance of software security, along with the science of security and the science of privacy. These investments also will address education and workforce issues related to cybersecurity. SaTC leverages NSF funding through joint programs with private industry and peer funding agencies.
- As part of its CEMMSS investment, CNS will continue to lead CPS (-$3.50 million to a total of $19.50 million) in partnership with five other federal agencies—Department of Homeland Security (DHS), Department of Transportation (DOT), National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH), and U.S. Department of Agriculture (USDA)—ENG, and other CISE divisions. As a critical underpinning of CEMMSS, CNS investment in CPS will support foundational interdisciplinary research and education in adaptive and pervasive smart systems supporting applications such as cyber-manufacturing, smart grid, intelligent transportation systems, and

medical devices. CNS will also continue to invest in NRI (-$2.0 million to a total of $2.50 million).

- CNS will continue to lead S&CC (level at $7.50 million) in partnership with EHR, ENG, GEO, SBE, and the other CISE divisions. CNS will pursue interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities, leading to enhanced quality of life for residents.
- CNS will transition support for CIF21 (-$6.50 million to a total of zero), investing in SPX (-$1.50 million to a total of $3.0 million) as part of NSCI and BIGDATA (level at $3.50 million) as part of HDR. CNS investments in NSCI will pursue foundational research leading to future HPC systems beyond the limits of current semiconductor technology, including addressing performance and scalability of parallel computing, cross-layer approaches, and novel systems architecture. CNS investments in HDR will support research on data-driven approaches to enhance performance, efficiency, and adaptability of computer systems, as well as the design and implementation of systems to support collection, curation, storage, and processing of massive data sets.
- CNS will continue to invest in UtB (-$290,000 to a total of $1.45 million), supporting research leading to improved systems for collection and analysis of physiological, cognitive, and behavioral data.
- CNS will discontinue support for INFEWS (-$2.50 million to a total of zero) and R&R (-$3.50 million to a total of zero), but will continue to support research related to these areas through investments in CEMMSS, notably CPS and S&CC.

Education

- CNS will continue to invest in NSF INCLUDES (+$130,000 to a total of $1.0 million) to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved or underrepresented in STEM.
- CNS will continue to invest in CSforAll (level at $1.50 million), in partnership with EHR, which seeks to enable rigorous and engaging computer science education in schools across the Nation. This investment will enlarge the pool of K-14 students and teachers who develop and practice computational competencies in a variety of contexts, thus advancing the 21st-century digital economy.
- CNS will continue to invest in REU sites and supplements (-$2.62 million to a total of $5.0 million).
- CNS will continue to invest in NRT (level at $490,000) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.
- CNS will invest in novel approaches for "CS+X" (+$20,000 to a total of $2.0 million) through IUSE, enabling the diffusion of the fundamentals of computational thinking and computer science across a broad array of other disciplines at the undergraduate level.

Infrastructure

- CNS will continue to invest in CISE Research Infrastructure (CRI) (level at $18.0 million), supporting the acquisition, enhancement, community access, and operation of state-of-the-art computing research infrastructure enabling high-quality computing research and education.
- CNS will continue to invest in the development of world-class, mid-scale research infrastructure (-$1.99 million to a total of $10.0 million) through NSFFutureCloud, Platforms for Advanced Wireless Research (PAWR), and Tomorrow's Internet Project Office (TIPOFF). 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 computing and communication infrastructure. Through PAWR, CNS will support the development of city-scale testbeds that enable research on topics ranging from dynamic spectrum sharing to mobility to measurement and monitoring, thus advancing the next generation of high-performance, robust wireless networks. As part of TIPOFF, CNS will engage the research community to envision, design, deploy and operate highly advanced experimental infrastructure for distributed computing systems.

DIVISION OF INFORMATION AND INTELLIGENT SYSTEMS (IIS) $174,750,000 -$20,050,000 / -10.3%

IIS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$194.80**	**-**	**$174.75**	**-$20.05**	**-10.3%**
Research	**184.86**	**-**	**165.25**	**-19.61**	**-10.6%**
CAREER	16.75	-	13.80	-2.95	-17.6%
Centers Funding (total)	1.00	-	1.00	-	-
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	1.00	-	1.00	-	-
Education	**9.94**	**-**	**9.50**	**-0.44**	**-4.4%**

IIS contributes to scientific advancement, economic growth, human health, and national security by studying the interrelated roles of people, computers, and information. IIS supports research and education activities that develop new knowledge about the role of people in the design and use of information technology with the goal of advancing human capabilities. IIS activities also increase our capability to create, manage, and understand data and information in systems ranging from implanted nano-processors to hand-held computers and globally-distributed systems. IIS research advances our understanding of how computational systems can exhibit the hallmarks of intelligence through investments in artificial intelligence, computer vision, robotics, machine learning, natural language processing, computational neuroscience, cognitive science, and related areas. These activities lay the foundation for work at the human-technology frontier by improving our understanding of how constantly evolving technologies are actively shaping our lives and how we in turn can shape those technologies, especially in a 21st-century digital society.

In general, 73 percent of the IIS portfolio is available for new research grants and 27 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- IIS will continue to invest in early-career researchers through CAREER (-$2.95 million to a total of $13.80 million).
- IIS will continue to lead the NRI program (-$2.35 million to a total of $14.50 million) 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. As a key component of CEMMSS, NRI focuses on human-centered research in developing service robots, requiring significant advances in human-robot interaction. IIS will focus on fundamental research in robotics, including advanced sensing, control, and power sources; integrated problem-solving architectures and decision algorithms; and safe, flexible and resilient structures. Application domains will include robots as co-workers in advanced manufacturing environments; aides supporting emergency responders and warriors in the field, thereby enhancing our emergency and defense preparedness; and service robots assisting the elderly to live

independently, consequently sustaining quality of life while diminishing costs of care. As part of its CEMMSS investment, IIS will continue to invest in CPS (-$3.50 million to a total of $1.0 million).

- IIS will transition support for CIF21 (-$9.50 million to a total of zero), investing in BIGDATA (level at $9.50 million) as part of HDR. IIS investments in HDR 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.
- IIS will invest in S&CC (+$1.50 million to a total of $1.50 million), pursuing interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities, leading to enhanced quality of life for residents.
- IIS will continue to invest in UtB (-$910,000 to a total of $11.80 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, with implications for ultimately limiting the effects of mental illness and compensating for cognitive decline.
- IIS will continue to lead SCH (-$2.0 million to a total of $7.0 million) in partnership with six NIH institutes, ENG, SBE, and other CISE divisions. IIS will pursue improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies, which will contribute to improved well-being and reduced health care costs.
- IIS will continue to lead Cyberlearning and Future Learning Technologies (CFLT) (-$6.67 million to a total of $5.50 million) in partnership with EHR and other CISE divisions. 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. New emphasis will be given to the use of technologies based on advances in artificial intelligence, cognitive aids, and learning science to support adult retraining and continuing education, thereby enabling increased employability in higher-paying jobs.
- IIS will continue to invest in SaTC (-$1.40 million to a total of $7.55 million), supporting research in cybersecurity and privacy, with an emphasis on data science, usability, and socio-technical as well as human-centered approaches.
- IIS will continue to invest in one STC, the Center for Brains, Minds and Machines: The Science and the Technology of Intelligence at MIT (level at $1.0 million), along with the CCF and ITR divisions.

<u>Education</u>

- IIS will continue to invest in NRT (level at $500,000) to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training focusing on areas of national priority.
- IIS will continue to invest in CSforAll (level at $4.0 million), which seeks to enable rigorous and engaging computer science education in schools across the Nation.
- IIS will continue to invest in REU Sites and Supplements (-$390,000 to a total of $4.40 million).

DIVISION OF INFORMATION TECHNOLOGY RESEARCH (ITR) — $83,510,000 / -$9,580,000 / -10.3%

ITR Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$93.09**	**-**	**$83.51**	**-$9.58**	**-10.3%**
Research	**79.66**	**-**	**69.57**	**-10.09**	**-12.7%**
CAREER	1.00	-	-	-1.00	-100.0%
Centers Funding (total)	1.00	-	1.00	-	-
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	1.00	-	1.00	-	-
Education	**4.17**	**-**	**1.94**	**-2.23**	**-53.4%**
Infrastructure	**9.26**	**-**	**12.00**	**2.74**	**29.6%**
Research Resources	9.26	-	12.00	2.74	29.6%

ITR contributes to scientific advancement, economic growth, human health, and national security by providing support for transformative explorations in computer and information science and engineering research, infrastructure, and related education activities, emphasizing the funding of innovative, high-risk/high-reward, multi-investigator projects.

In general, 59 percent of the ITR portfolio is available for new grants and 41 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- ITR will continue to invest in NSF I-Corps™ (-$2.06 million to a total of $9.65 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 further grow and sustain a national innovation ecosystem that continues to augment the development of technologies, products, and processes.
- ITR will continue to invest in center-scale Expeditions in Computing (-$4.0 million to a total of $8.0 million). Expeditions projects will continue to pursue transformative research agendas that promise to accelerate discovery at the frontiers of computer and information science and engineering.
- In collaboration with ENG, ITR will continue to invest in innovative partnerships and collaborations between academia and industry. As part of this investment, ITR will support Industry/University Cooperative Research Centers (IUCRCs) (-$1.0 million to a total of $7.0 million).
- ITR will continue to invest in S&CC (level at $6.0 million), pursuing interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities, leading to enhanced quality of life for residents.
- As part of NSCI, ITR will invest in SPX (level at $1.0 million) to pursue foundational research leading to future HPC systems beyond the limits of current semiconductor technology.

- ITR will continue to invest in 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).
- ITR will continue to invest in one STC, the Center for Brains, Minds and Machines: The Science and the Technology of Intelligence at MIT (level at $1.0 million), along with the CCF and IIS divisions.

Education

- ITR will continue to invest in NSF INCLUDES (-$70,000 to a total of $780,000) to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved or underrepresented in STEM.
- ITR will continue to invest in NRT (-$1.69 million to a total of $1.01 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 continue to invest in the development of world-class, mid-scale research infrastructure (+$2.74 million to a total of $12.0 million) through NSFFutureCloud and PAWR. 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. Through PAWR, ITR will support the development of city-scale testbeds that will enable research on topics ranging from dynamic spectrum sharing to mobility to measurement and monitoring, to enable the next generation of high-performance, robust wireless networks.

APPENDIX A – HIGH-PERFORMANCE COMPUTING PORTFOLIO

High Performance Computing Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Petascale Computing	$8.33	-	$60.00
Innovative HPC Program	42.82	-	19.50
Extreme Digital (XD)	45.50	-	10.00
Total	**$96.65**	**-**	**$89.50**

NSF has been a leader in the use of High-Performance Computing (HPC) to advance discovery for almost four decades. NSF aims to sustain its leadership in the research, development, and broad deployment of existing as well as new HPC technologies and skills in part through its leadership of the National Strategic Computing Initiative (NSCI) in partnership with the Department of Defense (DOD) and Department of Energy (DOE), and together with the participation of other federal agencies and the private sector. OAC co-leads NSCI with MPS, and represents NSF in its leadership role across the federal government. Key foci include fundamental discoveries to support future generations of advanced computing; research and cyberinfrastructure promoting cohesive platforms and interoperability for large-scale data analytics as well as modeling and simulation; and support for a comprehensive advanced computing ecosystem for science and engineering research. These foci include an emphasis on a holistic approach to the Nation's science and engineering computational infrastructure as well as learning and workforce development.

The overall NSF HPC strategy and program portfolio receives guidance and input from the Advisory Committee for Cyberinfrastructure (ACCI); NSF cross-directorate Assistant Directors (AD) Council, which includes ADs and Office Heads from the various NSF research directorates and offices; and the cross-directorate working group for NSCI. In 2013, ACI supported the initiation of a two-year National Academies' study to further inform the implementation of its HPC strategy in the 2017 to 2020 timeframe. The National Academies published the final report, *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering in 2017-2020*, in 2016.[20]

PETASCALE COMPUTING – BLUE WATERS

<u>Description</u>

A key component of NSF's current HPC investment is its support of a "leadership-class" HPC resource called Blue Waters. Blue Waters, one of the most powerful supercomputers in the world and the fastest supercomputer deployed on a university campus, is based at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC). The Blue Waters system became 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.

Since becoming operational in 2012, Blue Waters has allowed researchers to tackle much larger and more complex research challenges than ever before possible across and within disciplines as diverse as biology, astronomy, engineering, materials science, and the geosciences. Examples of transformational research enabled by Blue Waters include: biophysicist Klaus Schulten and his team at UIUC used experimental data combined with simulations on Blue Waters to discover the precise chemical structure of the hard-shell

[20] www.nap.edu/catalog/21886/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-and-engineering-in-2017-2020

capsid encasing the HIV virus (with funding from NIH)[21]; a public-private collaboration among multiple federal agencies, universities, and companies brought together data, expertise, and the unique capabilities of Blue Waters to create the first-ever publicly-available, high-resolution elevation maps of the Arctic[22]; and ExxonMobil geoscientists and NCSA recently demonstrated a massive parallel reservoir simulation that ran thousands of times faster than typical oil and gas industry reservoir simulations, in turn allowing faster, more cost-effective, and environmentally-responsible decisions.[23]

Blue Waters complements the diverse set of national resources provided through the Innovative HPC program and eXtreme Digital (XD) environment described below. While Innovative HPC supports a portfolio of technically diverse systems capable of supporting hundreds to thousands of researchers over the course of a year, Blue Waters provides resources to focus on a small set of the largest and most computationally intensive scientific advances demanding petascale capabilities. (For more information on Innovative HPC, see the "Innovative HPC Program" section below.) XD differs as well from Blue Waters in that XD delivers a more diverse set of capabilities generally at smaller scale but to a much larger community. (For more information on XD, see the "XD Program" section below.)

The broader impacts of Blue Waters include provisioning unique infrastructure for research and education; extensive efforts accelerating education and training in the use of HPC in science and engineering; 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 and engineering 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

Following system testing and acceptance in December 2012, and acceptance of the NCSA archival system in March 2013, the Blue Waters project entered a five-year operations phase. 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 provided in a separate award to UIUC in FY 2013.

The Blue Waters education and outreach projects are ongoing; they target pre-college, undergraduate, graduate, and post-graduate students. For example, a 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, conferences, summer schools, and seminars. An annual series of Petascale Workshops is targeted at the developers of simulation packages and aspiring application developers, and provides scientists and engineers with the knowledge and expertise needed to develop applications for Blue Waters and other petascale computers. The project also includes 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. In addition, annual extreme-scale workshops are held jointly with the Extreme Science and Engineering Discovery Environment (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,

[21] https://news.illinois.edu/blog/view/6367/204804
[22] http://nga.maps.arcgis.com/apps/MapSeries/index.html?appid=cf2fba21df7540fb981f8836f2a97e25
[23] www.ncsa.illinois.edu/news/story/exxonmobil_sets_record_on_ncsas_blue_waters_supercomputer

the Blue Waters project offers undergraduate petascale course materials and internships.

Despite the success of the Blue Waters supercomputer, the system is reaching its natural obsolescence, and will complete its operational cycle in March 2019, when a no-cost extension for the operations and maintenance award of the system, approved by NSF in FY 2016, ends. With the extension of the operational end date of Blue Waters to 2019, the system will have run for roughly two years longer than the typical lifetime for a system of this type. Among the activities anticipated in FY 2018 is support for a follow-on leadership-class computing resource, succeeding Blue Waters and with attributes to be determined based on scientific and engineering priorities.

Continuation of the program beyond the operational end date of Blue Waters is guided by input from a number of stakeholder groups. These include the ACCI; AD Council; NSF program staff spanning the Foundation's research directorates and offices; the cross-directorate NSCI working group; and the National Academies' study section mentioned above. Additionally, international activities to accelerate investments in leadership-class computing, particularly in Europe and Asia, are providing additional urgency and importance for this investment strategy to maintain the Nation's global leadership role in science and engineering.

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, allocations of time on Blue Waters are awarded to research teams through the NSF Petascale Computing Resource Allocations (PRAC) program. To date, the PRAC program has received over 448 requests for usage to support research across a wide spectrum of scientific and engineering disciplines, and it has made 233 awards to research teams—a 95% over-subscription request rate. The next PRAC call is anticipated in November 2017. The research topics the PRAC program supports include: complex biological behavior in fluctuating environments; electronic properties of strongly correlated systems; properties of hydrogen and hydrogen-helium mixtures in astrophysically-relevant conditions; electronic and magnetic structures of transition metal compounds; molecular dynamics responsible for the properties of liquid water; and propagation of seismic energy through a detailed structural model of Southern California together with 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; 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.

To date, 89 science teams have published over 618 scientific papers based on research conducted using Blue Waters allocations. Furthermore, the project has issued calls for educational allocations directly involving students, including the Blue Waters Undergraduate Student Internship Program (20 students in 2016) and Blue Waters Graduate Fellowship Program (10 awards in 2016). After three years in service, Blue Waters has supported research in 219 U.S. academic institutions, 40 laboratories, institutes, and centers, and 21 industrial organizations.

Management and Oversight

NSF Structure: The project is overseen by OAC's program directors and NSF Division of Grants and Agreement (DGA) staff. These NSF staff receive strategic advice from the AD Council. Advice from the NSF Office of General Counsel (OGC) is also sought as necessary.

External Structure: During the development and acquisition phase of this project, UIUC oversaw work by a number of sub-awardees, conducted software development, and assisted competitively-selected research groups to prepare to use the Blue Waters system. 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 project team is advised by the Science and Engineering Team Advisory Committee (SETAC) whose composition and roles were reviewed and approved by an external panel in July 2013. This Committee is composed of representatives from research teams with Blue Waters allocations, industry scientists pursuing petascale applications, and the GLCPC.

Risks: The National Science Board (NSB) will receive 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: The project was initially selected through a competitive merit review process in 2007, and a subsequent renewal proposal was reviewed and approved in 2013. 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, December 2015, and January 2017. OAC staff provided an update to the NSB in February 2015. Detailed information on the project's progress can be found in the project's publically-available annual reports.[24]

INNOVATIVE HPC PROGRAM

Description

Systems funded under the Innovative HPC program provide petascale peak performance. The Innovative HPC program portfolio is intended to be technically diverse, reflecting changing and growing use of computation in both the research and education processes, including through systems capable of supporting hundreds to thousands of researchers (over the course of a year) conducting leading-edge science and engineering. Additionally, the Innovative HPC program portfolio supports, complements, and extends campus and regional research cyberinfrastructures. All Innovative HPC program awards are made in the context of the XD program (described below).

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 program 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 a system has passed the acceptance process, vendors receive final payment for the system. After the system has been fully tested, 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 Innovative HPC program 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

[24] https://bluewaters.ncsa.illinois.edu/annual-report

value and time required for building and retaining staff skilled in interdisciplinary computational science. Thus, an eight- to 10-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 awards are planned.

Current Status

Machines that have been operational in the Innovative HPC program over the years include Stampede, Blacklight, Darter, FutureGrid, Gordon, Keeneland, Kraken, Lonestar, Longhorn, and Trestles. Of these, Stampede continues to be supported by NSF. In addition, four new resources, Comet, Bridges, Jetstream, and Wrangler, began operation in FY 2015 and FY 2016.

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. The system 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, with bandwidth of one terabyte per second (TB/s) and 275 million Input/Output Operations Per Second (IOPS). Wrangler further 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, starting in FY 2015 and continuing through FY 2019, is provided to the University of Texas at Austin at a level of approximately 20 percent of the initial acquisition cost per annum, consistent with the level specified in the FY 2013 Innovative HPC program solicitation.

Comet also came online in FY 2015 at the University of California, San Diego. It was deployed to support research interests and priorities requiring large, high-throughput workloads as well as 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 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.

Bridges came online in FY 2016 at the Pittsburgh Supercomputing Center on the campus of Carnegie Mellon University. Bridges provides an innovative and groundbreaking HPC and data analytics system integrating advanced memory technologies to empower new communities, bringing desktop convenience to HPC, connecting to campuses, and intuitively integrating data-intensive workflows to increase the scientific output of a large community of scientific and engineering researchers who have not traditionally used HPC resources by lowering the barrier of entry to HPC. Bridges extends HPC’s impact to minority-serving institutions and Established Program to Stimulate Competitive Research (EPSCoR) states, raising the level of computational awareness at four-year colleges, and promoting computational thinking in high-schools.

The fourth resource, Jetstream, also came online in FY 2016 at Indiana University. Jetstream is a new type of data analytics and computational resource for the open science and engineering research community, enabling interactive use by researchers to conduct research anytime, anywhere. Jetstream 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 data and computational analysis, allowing for increased scientific reproducibility and enabling many U.S. scientists 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.

Bridges and Jetstream, singularly and collectively, significantly broadened the spectrum of system capabilities supported by OAC's Innovative HPC program by delivering innovative computational resources to an increasingly diverse community and portfolio of scientific research and education projects, with the goal of including new communities with new and creative approaches and priorities that are different from the more traditional HPC users, and that would benefit from advanced computational capabilities at the national level.

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 will continue to operate through September 2017. The resources and accompanying services target science and engineering researchers using both advanced computational methods and emerging data-intensive approaches. The system boosted XD resources to nearly twice their previous capacity, and provided researchers with early access to Intel Many Integrated Core (MIC) processors, which were accepted in August 2013. An additional technical upgrade to Stampede was awarded in FY 2016, adding 508 updated "Knights Landing" processors and an Omni Path highspeed interconnect to the system contributing two-fold value to advance research. This technical upgrade provided significantly increased memory and enhanced performance for researchers, along with a production operations platform for researchers to bridge to future many-core computing architectures and computational parallelism through 2021.

Consistent with the FY 2011 Innovative HPC program solicitation, *High Performance System Acquisition: Enhancing the Petascale Computing Environment for Science and Engineering*, that resulted in the acquisition, development, and deployment of Stampede, in FY 2016 NSF awarded *Stampede 2: The Next Generation of Petascale Computing for Science and Engineering* to the University of Texas at Austin following a rigorous merit review, enabling the acquisition, development, and deployment of "Stampede 2" as a successor resource to Stampede. Stampede 2 will serve as the primary national resource ("workhorse") for thousands of U.S. academic researchers, complement other national HPC resources, and provide capabilities beyond the reach of campuses and regional resources, including support for multiscale modeling, simulation, and data-intensive research. Stampede 2 will be deployed into production operation through three phases: progressive installations of Knights Landing many-core nodes responsive to interests in high computation processing; addition of highly complementary SkyLake processors responsive to data-intensive computing; and final deployment of persistent memory to the previously deployed Skylake processors to significantly enhance overall system performance. Stampede 2 will serve the high-end, open science community through production operations beginning in FY 2017 and continuing through FY 2021.

Science and engineering research and education activities enabled by Innovative HPC

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, the Innovative HPC program enables researchers to manipulate extremely large amounts of digital information from simulation, sensors, and experiments, and adds needed capabilities in remote visualization, an increasingly important analysis tool for modern science and engineering. The complete spectrum of scientific research can leverage Innovative HPC program resources. This includes economics, cosmology and astrophysics, geosciences, climate and weather modeling, physics, chemistry, biology and medicine, earthquake engineering, and mechanical engineering.

Outreach and training critical to reducing the barriers to the use of systems supported by the Innovative HPC program by the research and education community will be provided by engaging research universities and foundations. The Innovative HPC program 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: OAC's program directors provide direct oversight during both the acquisition and operations and maintenance phases. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors. The program directors also hold bi-weekly teleconferences with the awardees.

External Structure: Each Innovative HPC program award is managed under a cooperative agreement. Each awardee is responsible for the satisfactory completion of milestones in order for the spending authorization to be raised. Progress is assessed by annual reviews and the NSF program directors.

Each project has a detailed management plan in place. Each cooperative agreement includes the management structure, milestones, spending authorization levels, and review schedule.

Risks: Any activity of this nature, and at this scale, comes with a certain element of risk. The review process, conducted prior to award, analyzes the risks as presented in the proposal and identifies any additional risks that should be considered. The funded projects 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 substantially reduced subsequent to deployment. Thus, pacing of acquisitions and deployments allows balance in overall portfolio risk for the Innovative HPC program.

Reviews: Semi-annual reviews are typically performed during the acquisition phase. Annual reviews, conducted by an external panel of expert reviewers, are performed during the operational phase of each project. OAC program directors manage the reviews. The reviewers' backgrounds include scientific research, project management, large-scale systems acquisitions and operations, and familiarity with projects funded by NSF as well as other federal agencies. To the extent possible, continuity through this series of reviews is provided by using the same set of reviewers.

EXTREME DIGITAL (XD) PROGRAM

Description

The Extreme Digital (XD) program adds value to the Innovative HPC program by coordinating the HPC resources, providing advanced assistance to the user community, and broadening participation. The vision is to create and sustain an advanced, nationally-distributed, open cyberinfrastructure comprising 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 infrastructure 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) is a separate award, while all other services constitute the XSEDE project. These elements are designed and implemented in a way that is clearly tied 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 individual users 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. The smaller XMS award was made in 2015 to the University at Buffalo – The State University of New York. This award provides metrics services allowing measurement of key operational data for both resources and services. The XSEDE award to UIUC was renewed in September 2016, continuing the prior XSEDE award for another five-year period. There are 18 XSEDE partners engaged via subawards to the University of Tennessee at Knoxville (National Institute for Computational Sciences), Carnegie Mellon University and University of Pittsburgh (Pittsburgh Supercomputing Center), University of Texas at Austin (Texas Advanced Computing Center), University of California, San Diego (San Diego Supercomputing Center), University of Chicago, Indiana University, Purdue University, Shodor Education Foundation, Ohio Supercomputer Center, Southeastern Universities Research Association, Cornell University, National Center for Atmospheric Research (NCAR), Georgia Institute of Technology, Oklahoma State University, University of Georgia, Oklahoma University, University of Southern California, and University of Arkansas. XSEDE has annual external reviews at NSF, with the first review of the renewed project scheduled to take place in June 2017.

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.

XD's XMS project develops novel methods and tools to collect data from a diverse set of sources, to store the data, and to provide user interfaces for viewing the data by different stakeholder communities. The immediate users of these methods and tools are the operators and users of NSF's HPC resources. However, the new principles and methods have the potential to reach broad communities in research and education that deal with the collection, storage, analysis, and use of data.

Management and Oversight

NSF Structure: OAC's program directors oversee the XD projects. XSEDE has an external advisory board, a user board, and a service provider forum to ensure that all stakeholders can provide project input. OAC 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. Each awardee is responsible for the satisfactory completion of milestones prior to processing of grant increments. Each project has a detailed management plan in place. Each cooperative agreement includes the management structure, milestones, spending levels over time, and review schedule.

Risk: While XD is operational in nature, the virtual organizations of the XSEDE project and the services of all 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: Annual reviews (for XSEDE) and mid-project reviews (for XMS) are conducted by external panels of expert reviewers. OAC program directors manage these 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. To strike a balance between continuity and broad community engagement, approximately half of the annual review panel members have served in this role previously while the other half are new members.

DIRECTORATE FOR ENGINEERING (ENG) $833,490,000

-$82,190,000 / -9.0%

ENG Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Chemical, Bioengineering, Environmental, and Transport Systems (CBET)	$183.76	-	$168.20	-$15.56	-8.5%
Civil, Mechanical, and Manufacturing Innovation (CMMI)	216.27	-	202.20	-14.07	-6.5%
Electrical, Communications, and Cyber Systems (ECCS)	113.89	-	102.85	-11.04	-9.7%
Engineering Education and Centers (EEC)	107.51	-	100.28	-7.23	-6.7%
Industrial Innovation and Partnerships (IIP)	239.87	-	223.21	-16.66	-6.9%
Emerging Frontiers and Multidisciplinary Activities (EFMA)	54.37	-	36.75	-17.62	-32.4%
Total	**$915.68**	**-**	**$833.49**	**-$82.19**	**-9.0%**

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—such as nanotechnology-enabled consumer, industrial, and healthcare products and manufacturing; resilient infrastructure to withstand disaster and disruption; novel light-based devices and tools for brain-related research and neurological imaging; secure, efficient devices and systems for communications and computing; and Internet-enabled smart manufacturing systems and supply chains—that in turn have stimulated economic growth and are improving the quality of life for all Americans.

In FY 2018, ENG's approach aims to bring about new breakthroughs for national priorities and grand challenges by (1) implementing NSF-wide investment priorities, and (2) supporting core programs in frontier engineering research and education.

The directorate will continue to invest throughout its core programs in emerging and frontier basic research areas, such as advanced materials and manufacturing; systems science and engineering; engineering biology; the food-energy-water nexus; and secure, next-generation electronic devices and systems.

In addition, ENG will help launch exciting technological innovations and support the Nation's innovation ecosystem through support for three main activities:

- Academic partnerships with industry via Engineering Research Centers (ERCs), Industry-University Cooperative Research Centers (IUCRCs), Grant Opportunities for Academic Liaison with Industry (GOALI), and Partnerships for Innovation (PFI),
- Experiential entrepreneurship training through NSF Innovation Corps (I-Corps™), and
- Small business R&D via the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

ENG will help prepare the future engineering workforce through leadership in engineering education research and hands-on research opportunities for both undergraduate and graduate students. Enrollment in engineering programs continues to grow significantly across the Nation. At the same time, the engineering education ecosystem continues to face major challenges in attracting women and underrepresented groups. ENG will continue its investments to identify and support systemic innovations to meet these critical and compelling challenges.

ENG will also lead or contribute directly to 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 funding of disciplinary and multidisciplinary research lays the groundwork for crucial aspects of the NSF Big Ideas. ENG investments contribute to Harnessing the Data Revolution through, for example, fundamental research in data-driven engineered systems for smart and connected communities and cyber-physical systems, spectrum efficiency and sharing, and devices and systems for the Internet of Things. The directorate creates a foundation for Quantum Leap through, for example, support for quantum sensing, communication and computing research, and investment in quantum technologies for secure communication systems. ENG investment supports Work at the Human–Technology Frontier through research in robotics, smart materials, control and communication systems, and other areas. ENG supports Understanding the Rules of Life by investing in nanotechnologies that help reveal life's fundamental processes, biomechanics and tissue engineering, and new methods for engineering biology. ENG investments contribute to Navigating the New Arctic through research in water supply and treatment, sustainability, advanced materials, and resilient infrastructure. The directorate is a committed partner to NSF INCLUDES and provides critical leadership for engineering communities. ENG has made a special contribution to Growing Convergent Research by originating the concept of convergence nearly 15 years ago as an outgrowth of the National Nanotechnology Initiative.

ENG provides about 43 percent of federal funding for basic research at academic institutions in the engineering sciences.

Major Investments

ENG Major Investments
(Dollars in Millions)

Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
BioMaPS	$1.50	-	-	-$1.50	-100.0%
CAREER	84.19	-	76.00	-8.19	-9.7%
CEMMSS	110.00	-	101.25	-8.75	-8.0%
Advanced Manufacturing	*98.00*	-	*90.00*	*-8.00*	*-8.2%*
CIF21	8.00	-	-	-8.00	-100.0%
I-Corps™	13.08	-	13.00	-0.08	-0.6%
NSF INCLUDES	1.41	-	1.40	-0.01	-0.9%
INFEWS	9.84	-	5.00	-4.84	-49.2%
IUSE	6.90	-	-	-6.90	-100.0%
NRT[1]	2.59	-	-	-2.59	-100.0%
Risk and Resilience	12.00	-	10.00	-2.00	-16.7%
SaTC	3.25	-	3.25	-	-
SEES	3.00	-	-	-3.00	-100.0%
Understanding the Brain	18.00	-	16.75	-1.25	-6.9%
BRAIN Initiative	*18.00*	-	*16.75*	*-1.25*	*-6.9%*

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

[1] In FY 2016, the NRT line includes a final funding increment of $1.81 million for the Integrative Graduate Education and Research Traineeship (IGERT).

All funding decreases/increases represent changes over the FY 2016 Actual.

- BioMaPS (-$1.50 million, to a total of zero): ENG formal support for Research at the Interface of the Biological, Mathematical and Physical Sciences (BioMaPS) ends as funds transition to core programs to support engineering biology.

- Faculty Early Career Development (CAREER) (-$8.19 million, to a total of $76.0 million): CAREER awards support promising junior faculty to serve as role models for outstanding research and education, and to lead advances in their organizational mission.

- CEMMSS (-$8.75 million, to a total of $101.25 million): ENG support for CEMMSS 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 (-$8.0 million, to a total of $90.0 million): ENG 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 an 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 NSF investments in fundamental research and education in manufacturing.

- CIF21 (-$8.0 million, to a total of zero): ENG sunsets Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) support as planned and transitions investment to the National Strategic Computing Initiative (NSCI), which advances knowledge to enable low-power computing and future high-performance computing (HPC) systems in the post-Moore's Law era.

- I-Corps™ (-$80,000, to a total of $13.0 million): ENG will continue to lead the NSF-wide I-Corps™ program. In FY 2018, ENG will support I-Corps™ Teams, Sites, and Nodes to further expand and sustain a national innovation ecosystem that trains high-tech entrepreneurs and accelerates the development of advanced technologies that benefit the Nation.

- NSF INCLUDES (-$10,000, 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 (-$4.84 million, to a total of $5.0 million): ENG will continue to co-lead this NSF-wide initiative with the Directorate for Geosciences (GEO) in FY 2018. The goal is to catalyze 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 (-$6.90 million, to a total of zero): ENG support for the NSF-wide Improving Undergraduate STEM Education (IUSE) initiative, which integrates the agency's investments in undergraduate education, will pause in FY 2018 as support for the IUSE/Professional Formation of Engineers: REvolutionizing engineering and computer science Departments (PFE:RED) solicitation moves to a biennial cycle. PFE:RED enables research and innovations leading to and propagating interventions that improve both the quality and quantity of engineering graduates.

- NSF Research Traineeship (NRT) (-$780,000, to a total of zero): ENG sunsets support for the NRT program.

- Risk and Resilience (-$2.0 million, to a total of $10.0 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 2018, ENG will continue to support the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program by catalyzing interdisciplinary research collaborations that deepen fundamental knowledge and stimulate innovations to improve resilience, interoperations, and performance of our critical infrastructure.

- Secure and Trustworthy Cyberspace (SaTC) ($3.25 million, equal to the FY 2016 Actual): 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, to a total of zero): ENG formal support for Science, Engineering, and Education for Sustainability (SEES) ends as planned. ENG will continue to support SEES-related research through unsolicited core programs.

- UtB (-$1.25 million, to a total of $16.75 million): ENG investments in neuroimaging and neurotechnology research are critical to success of the BRAIN Initiative. Research will drive integration across scales and disciplines; accelerate the development of novel experimental and analytical approaches, such as computational and data-enabled modeling; and enable neural technology innovation.

ENG Funding for Centers Programs and Facilities

ENG Funding for Centers Programs
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Centers Programs	**$67.14**	**-**	**$72.50**	**$5.36**	**8.0%**
Engineering Research Centers (EEC)	56.39	-	57.50	1.11	2.0%
Nanoscale Science and Engineering Centers (Multiple)[1]	0.75	-	-	-0.75	-100.0%
Science & Technology Centers (Multiple)	10.00	-	15.00	5.00	50.0%

[1] The Nanoscale Centers program will sunset as planned in FY 2017.

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

ENG Funding for Facilities
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Facilities	**$29.70**	**-**	**$26.58**	**-$3.12**	**-10.5%**
Cornell High Energy Synchrotron Source (CHESS)	5.00	-	4.00	-1.00	-20.0%
National Nanotechnology Coordinated Infrastructure (NNCI)	11.70	-	10.83	-0.87	-7.4%
Natural Hazards Earthquake Engineering Research Infrastructure (NHERI)	13.00	-	11.75	-1.25	-9.6%

For detailed information on individual facilities, see the Facilities and the Major Research Equipment and Facilities Construction chapters.

Funding Profile

ENG investments support fundamental engineering research, engineering education, and innovation, as well as research infrastructure such as facilities.

In FY 2018, the number of competitive proposals received, which includes SBIR/STTR proposals, is expected to be about 12,800, which includes about 10,000 research grant proposals. ENG expects to award approximately 2,250 competitive grants, including an estimated 1,600 research grants in FY 2018. Average annualized award size and duration are estimated to be $124,000 and 2.7 years, respectively, in FY 2018.

In FY 2018, funding for centers accounts for 11 percent of ENG’s non-SBIR/STTR Request.

In FY 2018, funding for facilities is just over four percent of ENG's non-SBIR/STTR Request.

ENG Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	12,575	-	12,800
Number of New Awards	2,503	-	2,250
Funding Rate	20%	-	18%
Statistics for Research Grants:			
Number of Research Grant Proposals	9,883	-	10,000
Number of Research Grants	1,795	-	1,600
Funding Rate	18%	-	16%
Median Annualized Award Size	$102,789	-	$102,000
Average Annualized Award Size	$124,817	-	$124,000
Average Award Duration, in years	2.7	-	2.7

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- 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 arose from discussions NAE held with the NRC on the future of NSF's center-based, multidisciplinary engineering research. To help inform the study, the National Academies held a public symposium on April 6, 2016, and published a proceedings.[1] The study report[2], delivered May 2, 2017, articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research, which ENG will carefully consider for the path ahead.
- A study of the feasibility of performing rigorous impact evaluation of the I-Corps™ Teams program was completed in FY 2014. Based on the feasibility study, NSF initiated a rigorous evaluation of the I-Corps™ Teams program in FY 2016. A report will be available in FY 2018.
- During FY 2017, ENG engaged in developing an evaluation framework for the directorate that identifies outcomes to be monitored across programs so that individual program evaluation efforts are minimized. A measurement framework with four areas of activity: research, human capital development and partnerships, centers and networks, and construction of physical, virtual and cyber infrastructure was developed with participation of representatives from all divisions. It is expected that this framework will be used to develop an outcome monitoring system for all programs using internal Research Performance Progress Report (RPPR) data, external data sets (patents and bibliometric data), and potentially a common survey. This activity eliminated the need for individual longitudinal outcome monitoring systems (e.g., for the Emerging Frontiers in Research and Innovation (EFRI) program).
- In FY 2016, IIP collected data for the PFI: Accelerating Innovation Research (AIR) and PFI: Building Innovation Capacity (BIC) programs based on their theories of action and, in FY 2017, ENG finalized

[1] A Vision for the Future of Center-Based Multidisciplinary Engineering Research symposium proceedings: www.nap.edu/catalog/23645/a-vision-for-the-future-of-center-based-multidisciplinary-engineering-research

[2] A New Vision for Center-Based Engineering Research report: www.nap.edu/catalog/24767/a-new-vision-for-center-based-engineering-research

a report for the longitudinal outcomes of the PFI:AIR program to date. A report for the PFI:BIC program is being finalized.

Workshops and Reports:

- With support from ECCS, Boston University organized a Smart Cities workshop on December 3-4, 2015, and prepared a report.[3] The workshop brought together researchers and technical leaders from academia, industry, and municipal government to set a short- and long-term research agenda for emerging issues in Smart and Connected Communities. Such issues span a variety of fields and specialized disciplines such as: transportation, environment, energy, building design and management, urban planning, sensor and actuator networks, social science, economics, software platform design, and data management. The workshop outcomes were incorporated in the focus of the NSF solicitation, S&CC: Smart and Connected Communities (16-610), funded in FY 2017.
- With support from CBET, the Department of Energy and others, a National Academies workshop on The Changing Landscape of Hydrocarbon Feedstocks for Chemical Production-Implications for Catalysis was held on March 7-8, 2016. The workshop proceedings[4] identified gaps and opportunities in catalysis research in an era of shifting feedstocks, from crude oil to natural gas, for chemical production. This activity helps U.S. researchers and funding agencies understand the most critical areas of science and engineering research to help realize the potential of the shale gas revolution for the U.S. chemical industry.
- In FY 2016, EFMA co-funded a three-year study on Grand Challenges in Environmental Engineering by the National Academies of Sciences, Engineering, and Medicine.[5] The study will identify high-priority challenges for environmental engineering and science for the next several decades. The report will shape the growth of university departments, inspire the next generation of engineers and scientists to address the most pressing global environmental challenges, and improve the training of environmental engineers and scientists to better meet these challenges. It will also help inform NSF program directors of emerging areas for research. The first of three planned public workshops associated with the study was held May 4-5, 2017.
- CMMI supported a three-day workshop on Predictive, Theoretical, and Computational Approaches for Additive Manufacturing, hosted by the National Academies of Sciences, U.S. National Committee on Theoretical and Applied Mechanics during October 7-9, 2015. The goal of the workshop was to identify key knowledge gaps in theoretical and computational approaches to additive manufacturing from computer science, materials science, and engineering perspectives. The workshop identified key needs for an understanding of material behavior during additive processes, in-situ measurement and real-time analytic methods for process validation and control, multi-scale and multi-physics modeling, and increased leveraging of high power computing for predictive models of process-structure-property-performance relationships in additively produced parts, and the workshop proceedings[6] set out a roadmap for the additive manufacturing community. The activity motivated follow-up workshops on Mechanical Behavior of Additive Manufactured Components, sponsored by the American Society for Testing and Materials (ASTM) and the National Institute of Standards and Technology (NIST), as well as proposed additive manufacturing benchmark tests performed by researchers at NIST.
- In FY 2015, EFMA funded the Exploring Innovation Frontiers Initiative (EIFI), a two-year, national public-private effort to shape and strengthen future U.S. innovation and competitiveness led by the Council on Competitiveness. Diverse leaders from academia, industry, and government have participated in a series of regional dialogues during 2015-2016: at the Georgia Institute of Technology

[3] Smart Cities workshop report: www.bu.edu/systems/files/2016/07/NSFWorkshopReport_SmartCities_2015.pdf
[4] Changing Landscape of Hydrocarbon Feedstocks for Chemical Production workshop proceedings: www.nap.edu/catalog/23555/the-changing-landscape-of-hydrocarbon-feedstocks-for-chemical-production-implications
[5] Grand Challenges in Environmental Engineering project site: www8.nationalacademies.org/cp/projectview.aspx?key=49849
[6] Predictive Theoretical and Computational Approaches for Additive Manufacturing workshop proceedings: www.nap.edu/catalog/23646/predictive-theoretical-and-computational-approaches-for-additive-manufacturing-proceedings-of

on June 9, 2015; the University of California Riverside on November 23, 2015, and at Texas A&M University on November 15, 2016. A fourth regional dialogue will be held in June 2017 at Washington University in St. Louis. Reports from the EIFI workshops will help inform NSF and the community of actionable, interdisciplinary frameworks for next-generation business and research innovation models.

Committees of Visitors (COVs):

- In 2016, COVs reviewed EEC and IIP. The COVs presented their reports to the ENG Advisory Committee, which convened in April and October of 2016. Both COV reports were approved by the ENG Advisory Committee.
- In 2018, COVs will review ECCS and EFMA.
- In 2019, COVs will review CBET and CMMI.

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

Number of People Involved in ENG Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	9,187	-	8,800
Other Professionals	1,921	-	1,800
Postdoctoral Associates	418	-	400
Graduate Students	7,509	-	7,200
Undergraduate Students	4,366	-	4,100
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	23,401	-	22,300

DIVISION OF CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, AND TRANSPORT SYSTEMS (CBET) — $168,200,000 / -$15,560,000 / -8.5%

CBET Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$183.76**	**-**	**$168.20**	**-$15.56**	**-8.5%**
Research	**177.45**	**-**	**163.36**	**-14.09**	**-7.9%**
CAREER	43.49	-	36.00	-7.49	-17.2%
Centers Funding (total)	5.33	-	5.00	-0.33	-6.2%
Nanoscale Science and Engineering Centers	0.33	-	-	-0.33	-100.0%
STC: Center for Emergent Behavior of Integrated Cellular Systems	5.00	-	5.00	-	-
Education	**2.63**	**-**	**1.15**	**-1.48**	**-56.2%**
Infrastructure	**3.68**	**-**	**3.69**	**0.01**	**0.3%**
NNCI	3.68	-	3.69	0.01	0.3%

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, such as 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 (transport), and civil (environmental) engineering disciplines. To serve these communities and achieve its goals, CBET is organized into four thematic clusters: Chemical Process Systems; Engineering Biology and Health; Environmental Engineering and Sustainability; and Transport Phenomena.

In general, 79 percent of the CBET portfolio is comprised of new research grants, and 21 percent supports continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

<u>Research</u>

- CAREER funding represents over 21 percent of CBET's funding. CAREER funding decreases by $7.49 million, to a total of $36.0 million in FY 2018. This decrease will result in 15 fewer awards.
- Support for NSF-wide INFEWS decreases by $2.0 million, to a total of $5.0 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.

- CBET support for the NSF-wide CEMMSS investment decreases by $3.0 million, to a total of $7.0 million, as the DMREF program moves to a biennial solicitation and support for the National Robotics initiative within the division is discontinued.
- Support for Sustainable Chemistry, Engineering, and Materials will be reduced by $1.29 million as the NSF-wide SEES investment sunsets in FY 2017 as planned. Some support will continue in this important area through core unsolicited programs.
- Support for UtB research totals $7.0 million, equal to the FY 2016 Actual. 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 continue support for 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 support research in advanced biomanufacturing, through its core programs Cellular and Biochemical Engineering and Engineering Biomedical Systems, 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.
- Science and Technology Center (STC) funding is maintained at $5.0 million to continue support for the STC on Emergent Behaviors of Integrated Cellular Systems.
- CBET support for the Nanoscale Science and Engineering Center (NSEC) program decreases by $330,000, to a total of zero, as the program sunsets as planned.

<u>Education</u>

- CBET contributes to a number of education and diversity activities, including Research Experiences for Undergraduates (REU) and NSF’s Career Life Balance (CLB) activities. Total CBET funding for these activities in the FY 2018 Budget Request is $1.15 million.

<u>Infrastructure</u>

- CBET provides continued support for infrastructure in FY 2018 through investments in the National Nanotechnology Coordinated Infrastructure (NNCI) at the FY 2016 Actual level.

DIVISION OF CIVIL, MECHANICAL, AND MANUFACTURING INNOVATION (CMMI) — $202,200,000 / -$14,070,000 / -6.5%

CMMI Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$216.27**	**-**	**$202.20**	**-$14.07**	**-6.5%**
Research	**198.85**	**-**	**186.85**	**-12.00**	**-6.0%**
CAREER	25.47	-	25.00	-0.47	-1.9%
Centers Funding (total)	0.31	-	5.00	4.69	1512.9%
Nanoscale Science and Engineering Centers	0.31	-	-	-0.31	-100.0%
STC: Center for Mechano-Biology	-	-	5.00	5.00	N/A
Education	**2.53**	**-**	**1.70**	**-0.83**	**-32.7%**
Infrastructure	**14.90**	**-**	**13.65**	**-1.25**	**-8.4%**
NHERI	13.00	-	11.75	-1.25	-9.6%
NNCI	1.90	-	1.90	-	-

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, such as healthcare.

In general, 84 percent of the CMMI portfolio is comprised of new research grants and 16 percent supports continuing grants.

FY 2018 Summary

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

Research

- CAREER funding in FY 2018 decreases by $470,000, to a total of $25.0 million, resulting in one fewer award.
- Support for disciplinary and interdisciplinary research decreases by $10.32 million. Fundamental core research in support of advanced manufacturing will be maintained, to the extent possible, 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 engineering, smart manufacturing, and design and manufacturing of complex engineered systems. CMMI support of the CPS solicitation will be discontinued as support shifts to the Cybermanufacturing Systems program (created as a CMMI core program in FY 2016). Support of

DMREF research will pause as the activity moves to a biennial solicitation, and support for formal NRI activities will be reduced.

- Support for the agency's Risk and Resilience focus through the CRISP program will be maintained at $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.
- Support for Sustainable Chemistry, Engineering, and Materials will be reduced by $500,000 as the NSF-wide SEES investment sunsets in FY 2017 as planned.
- Support for CIF21 decreases by $400,000, to a total of zero, as the program sunsets as planned; focus shifts to investments in NSCI. Within NSCI, CMMI will continue to support research on computationally-based approaches for engineering design, analysis, and predictive modeling, particularly under high degrees of uncertainty.
- CMMI support for the NSEC program decreases by $310,000, to a total of zero, as the program sunsets as planned.
- STC funding increases by $5.0 million as CMMI initiates support of the Center for Mechano-Biology.

<u>Education</u>

- CMMI contributes to a number of education and diversity activities, including REU and CLB. Total CMMI funding for these activities in the FY 2018 Request is $1.70 million.

<u>Infrastructure</u>

- Support for NHERI decreases by $1.25M, to a total of $11.75 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 large NHERI facilities are distributed, multi-user, national facilities that provide the natural hazards engineering 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. The reduction in overall operations costs will require facilities managers to create leaner organizations, with the likely result that user fees may be increased to provide the necessary level of support to facility users.
- CMMI provides continued support for infrastructure through investments in the NNCI at the FY 2016 Actual level.

DIVISION OF ELECTRICAL, COMMUNICATIONS, AND CYBER SYSTEMS (ECCS) $102,850,000 -$11,040,000 / -9.7%

ECCS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$113.89**	**-**	**$102.85**	**-$11.04**	**-9.7%**
Research	**106.21**	**-**	**96.66**	**-9.55**	**-9.0%**
CAREER	14.72	-	15.00	0.28	1.9%
Centers Funding (total)	5.11	-	5.00	-0.11	-2.2%
Nanoscale Science and Engineering Centers	0.11	-	-	-0.11	-100.0%
STC: Center for Energy Efficient Electronics Science	5.00	-	5.00	-	-
Education	**1.56**	**-**	**0.95**	**-0.61**	**-39.0%**
Infrastructure	**6.12**	**-**	**5.24**	**-0.88**	**-14.4%**
NNCI	6.12	-	5.24	-0.88	-14.4%

ECCS addresses fundamental research issues underlying electronic and photonic devices and component technologies (such as bioelectronic, flexible, and quantum devices), power, controls, computation, networking, communications (such as secure, efficient spectrum utilization for wireless), and cyber technologies. The division supports the integration and networking of intelligent systems principles at the nano, micro, and macro scales for applications in: healthcare, security, disaster mitigation, energy, telecommunications, transportation, robotics, 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 future generations of innovative devices and systems.

In general, 80 percent of the ECCS portfolio is comprised of new research grants and 20 percent supports continuing grants.

FY 2018 Summary

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

Research

- CAREER funding increases by $280,000, to a total of $15.0 million, in FY 2018. This increase is consistent with ECCS's emphasis on supporting early-career researchers.
- ECCS support for the NSF-wide CEMMSS investment decreases by $3.50 million to a total of $10.68 million as the DMREF program moves to a biennial solicitation and support for the National Robotics initiative within the division is discontinued.
- Support for CIF21 activities will decrease $400,000, to a total of zero, 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 era of device and hardware 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 support decreases by $1.0 million, to a total of $5.0 million in support of 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 through the Spectrum Efficiency, Energy Efficiency and Security (SpecEES) activity.
- 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.
- ECCS maintains support, at $5.0 million, for the STC for Energy Efficient Electronics Science.
- ECCS support for the NSEC program decreases by $110,000, to a total of zero, as the program sunsets as planned.

Education
- ECCS contributes to a number of education and diversity activities, including REU and CLB. Total ECCS funding for these activities in FY 2018 is $950,000, a decrease of $610,000 from the FY 2016 Actual.

Infrastructure
- ECCS reduces support for infrastructure by $880,000, to a total of $5.24 million, through investments in the NNCI consistent with cooperative agreement funding levels.

DIVISION OF ENGINEERING EDUCATION AND CENTERS (EEC) — $100,280,000 / -$7,230,000 / -6.7%

EEC Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$107.51**	**-**	**$100.28**	**-$7.23**	**-6.7%**
Research	**81.79**	**-**	**83.85**	**2.06**	**2.5%**
CAREER	0.51	-	-	-0.51	-100.0%
Centers Funding (total)	56.39	-	57.50	1.11	2.0%
Engineering Research Centers	56.39	-	57.50	1.11	2.0%
Education	**25.72**	**-**	**16.43**	**-9.29**	**-36.1%**

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/life sciences and engineering, from nanostructured materials to new device concepts, subsystems, and systems. Applications range across a wide spectrum, such as energy, medicine, telecommunications, nanoelectronics, manufacturing, civil infrastructure, the environment, computer networks, cybersecurity, and others. Also included are formal scholarly studies in the professional formation of engineers, which can lead to innovations in engineering education and career development.

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 four categories: (1) Major Centers and Facilities; (2) Engineering Education Research; (3) Engineering Workforce Development; and (4) Broadening Participation in Engineering. Major Centers and Facilities is comprised of the signature Engineering Research Centers (ERC) program and the sunsetting Nanoscale Science and Engineering Centers (NSECs). They provide the framework for interdisciplinary research and education, development, and technology transfer in partnership with academia, industry, and government. Engineering Education Research 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. Engineering Career Development includes programs such as REU and Research Experiences for Teachers (RET). Broadening Participation in Engineering supports research and activities that enhance opportunities for underrepresented groups by addressing structural inequalities and biases within educational and workforce systems. This category also includes EEC's engagement with the NSF INCLUDES initiative, which integrates the agency's investments to build on and scale up what works in broadening participation programs.

In general, 26 percent of the EEC portfolio is comprised of new research grants. The remaining 74 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 2018 Summary

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

Research

- Support for the ERC program increases by $1.11 million, to a total of $57.50 million. This funding level provides support for 14 existing centers. 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 era of device and hardware systems. EEC's ERC portfolio includes four Nanosystems ERCs: three whose funding began in FY 2012 and one whose funding began in FY 2015.

Education

- In FY 2018, EEC will pause support (-$3.98 million, to a total of zero) for 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. The program is moving to an every-other-year solicitation cycle.
- Funding for the REU Sites program is decreased by $2.65 million, 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. REU 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 is increased by $20,000, 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, roughly equal to the FY 2016 Actual, to support the agency's broadening participation program NSF INCLUDES.

DIVISION OF INDUSTRIAL INNOVATION AND PARTNERSHIPS (IIP) — $223,210,000 / -$16,660,000 / -6.9%

IIP Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$239.87**	**-**	**$223.21**	**-$16.66**	**-6.9%**
Research	**239.31**	**-**	**223.06**	**-16.25**	**-6.8%**
SBIR/STTR	188.52	-	176.21	-12.31	-6.5%
Education	**0.57**	**-**	**0.15**	**-0.42**	**-73.6%**

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 cross-agency small business research programs, the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program. These programs seek to transform scientific discovery into societal and economic benefit by catalyzing private sector commercialization of technological innovations. The SBIR/STTR programs provide the opportunity for startups and small businesses to undertake cutting-edge, high-quality scientific research and development with the goal of achieving technology commercialization and enabling new products, processes, or services. SBIR/STTR technology topics draw upon the breadth of NSF scientific and engineering research disciplines and are aligned with national and societal priorities.

IIP also supports academic research through three research programs: Industry–University Cooperative Research Centers (IUCRCs), Partnerships for Innovation (PFI), and Grant Opportunities for Academic Liaison with Industry (GOALI). 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.

IIP also leads the I-Corps™ program that 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, 97 percent of the IIP portfolio is comprised of new research grants and 3 percent supports continuing grants.

FY 2018 Summary

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

Research

- Funding for SBIR/STTR decreases by $12.31 million, to a total of $176.21 million, consistent with the levels specified in the SBIR/STTR Reauthorization Act of 2011 (P.L 112-81), which stipulates 3.2

percent and 0.45 percent of NSF's FY 2018 extramural research funding be allocated to the SBIR and STTR programs, respectively. Support for SBIR/STTR will continue to provide resources to the small business community to embark on cutting-edge, high-risk, and high-impact research projects.
- Funding for the PFI program decreases by $3.90 million, to a total of $16.75 million as the program undergoes a restructuring in FY 2018. The restructured PFI program will provide a continuum of opportunities that enable academic research discoveries to be translated along a path toward commercial reality, while engaging faculty and students in entrepreneurial and market-oriented thinking and supporting academic-industry partnerships that can accelerate the innovation.
- Funding for the I-Corps™ program decreases by $80,000, to a total of $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, 892 Teams have completed this experiential education, and approximately 45 percent of these Teams have started their own companies; three of these companies have been acquired.
- Funding for IUCRC increases by $1.74 million, to a total of $12.50 million. Support in FY 2018 will include a "reverse" IUCRC pilot where industry members come together to identify pre-competitive research topics and NSF solicits proposals from university teams interested in the formation of an IUCRC in that area of research. IIP's support for GOALI decreases by $120,000 to $4.75 million. The program promotes university-industry partnerships by making project funds or fellowships/traineeships available to support an eclectic mix of industry–university linkages, including opportunities to support graduate students in industry experiences.

Education
- Support for the REU program decreases by $210,000 to a total of $150,000

OFFICE OF EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES (EFMA)

$36,750,000
-$17,620,000 / -32.4%

EFMA Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total	**$54.37**	**-**	**$36.75**	**-$17.62**	**-32.4%**
Research	**45.95**	**-**	**32.65**	**-13.30**	**-28.9%**
Education	**3.42**	**-**	**0.10**	**-3.32**	**-97.1%**
Infrastructure	**5.00**	**-**	**4.00**	**-1.00**	**-20.0%**
CHESS	5.00	-	4.00	-1.00	-20.0%

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 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 is intended to 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 have 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.

During FY 2014–2015, 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 (2-D) 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 and FY 2017, EFRI has been investing in two new topic areas. Advancing Communication Quantum Information Research in Engineering (ACQUIRE) aims to enhance secure, scalable, and efficient data communication. ACQUIRE researchers are investigating 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, EM (electronic), 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.

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 2018 Summary

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

Research

- In FY 2018 EFRI support decreases by $3.0 million, to a total of $27.75 million, and will provide support for up to 13 interdisciplinary team projects aimed at addressing national challenges such as renewable energy, advanced manufacturing, and secure communication systems.
- Other EFMA investments will decrease by $10.30 million in support of NSF-wide multidisciplinary investments and other important national priorities.

Education

- EFMA support for the ADVANCE program ends in FY 2018, and the REU program is maintained at $100,000.

Infrastructure

- EFMA reduces support for CHESS by $1.0 million, to a total of $4.0 million, consistent with plans to transition the facility from NSF stewardship to a partnership model, which would begin in FY 2018.

DIRECTORATE FOR GEOSCIENCES (GEO) $783,310,000
-$93,200,000 / -10.6%

GEO Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Atmospheric and Geospace Sciences (AGS)	$253.54	-	$227.68	-$25.86	-10.2%
Earth Sciences (EAR)	179.67	-	161.01	-18.66	-10.4%
Integrative and Collaborative Education & Research (ICER)	83.47	-	71.60	-11.87	-14.2%
Ocean Sciences (OCE)	359.83	-	323.02	-36.81	-10.2%
Total	**$876.51**	**-**	**$783.31**	**-$93.20**	**-10.6%**

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; and understanding future availability and distribution of fresh water.

In addition, the Office of Polar Programs (OPP) operates as part of the Directorate for Geosciences; more information on OPP can be found in the Office of Polar Programs narrative.

GEO provides about 59 percent of the federal funding for basic research at academic institutions in the atmospheric, earth, and ocean sciences.

Major Investments

GEO Major Investments
(Dollars in Millions)

Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
CAREER	$16.20	-	$13.71	-$2.49	-15.4%
NSF INCLUDES	2.56	-	2.20	-0.36	-14.1%
INFEWS	5.00	-	8.00	3.00	60.0%
IUSE	6.14	-	5.00	-1.14	-18.6%
NRT	4.35	-	2.50	-1.85	-42.5%
Risk and Resilience	16.75	-	17.25	0.50	3.0%

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

- Faculty Early Career Development (CAREER) (-$2.49 million to a total of $13.71 million): Supporting the next generation of researchers remains a priority for GEO, and the CAREER program continues to be a mechanism for recognizing the most innovative early career investigators.

- Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) (-$360,000 to a total of $2.20 million): In FY 2018, NSF continues to emphasize NSF INCLUDES, which started in FY 2016 and aims to promote broader participation in the sciences.

- Innovations at the Nexus of the Food, Energy, Water System (INFEWS) (+$3.0 million to a total of $8.0 million): In FY 2018, NSF is continuing to build an interdisciplinary investment to study the food-energy-water nexus through INFEWS to enable accelerated research at the food-energy-water nexus.

- Improving Undergraduate STEM Education (IUSE) (-$1.14 million to a total of $5.0 million): Funding for the NSF-wide IUSE activity continues to support development of the next generation of geoscientists.

- NSF Research Traineeship (NRT) (-$1.85 million to a total of $2.50 million): 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.

- Risk and Resilience (+$500,000 to a total of $7.25 million): In FY 2018, NSF is continuing an 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 through the Prediction of and Resilience against Extreme EVENTS (PREEVENTS) program.

GEO Funding for Centers Programs and Facilities

GEO Funding for Centers Programs

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Centers Programs	**$5.00**	**-**	**$5.00**	**-**	**-**
STC: Center for Dark Energy Biosphere Investigations (OCE)	5.00	-	5.00	-	-

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

GEO Funding for Facilities

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Facilities	**$335.08**	**-**	**$284.32**	**-$50.76**	**-15.1%**
Academic Research Fleet (OCE)	85.88	-	77.80	-8.08	-9.4%
Arecibo Observatory (AGS)	4.10	-	3.82	-0.28	-6.8%
Geodesy Advancing Geosciences and EarthScope (EAR)	11.87	-	10.90	-0.97	-8.2%
International Ocean Discovery Program (OCE)	48.00	-	48.00	-	-
National Center for Atmospheric Research (AGS)	105.60	-	89.90	-15.70	-14.9%
National Nanotechnology Coordinated Infrastructure (ICER)	0.30	-	-	-0.30	-100.0%
Ocean Observatories Initiative (OCE and ICER)	54.98	-	31.00	-23.98	-43.6%
Seismological Facilities for the Advancement of Geosciences and EarthScope (EAR)	24.35	-	22.90	-1.45	-6.0%

For detailed information on individual facilities, see the Facilities and the Major Research Equipment and Facilities Construction chapters.

Funding Profile

GEO supports investment in research and education as well as research infrastructure such as the National Center for Atmospheric Research.

In FY 2018, GEO anticipates receiving a similar number of proposals as received in FY 2016. However, fewer awards will be supported resulting in a general decrease in funding rates.

GEO Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,043	-	4,000
Number of New Awards	1,247	-	1,100
Funding Rate	31%	-	28%
Statistics for Research Grants:			
Number of Research Grant Proposals	3,675	-	3,700
Number of Research Grants	1,059	-	950
Funding Rate	29%	-	26%
Median Annualized Award Size	$149,381	-	$149,000
Average Annualized Award Size	$182,515	-	$182,000
Average Award Duration, in years	2.7	-	2.7

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- In FY 2017, GEO will initiate an evaluation of its Education and Diversity program. Results are expected to be used to inform internal strategic planning activities. Final results from this study are expected in FY 2018.
- GEO has one evaluation underway, summarized below:
  - The Science, Engineering, and Education for Sustainability (SEES) program, ending in FY 2017, is currently being assessed. The evaluation is being conducted by Manhattan Strategy Group and will 1) examine the effectiveness of SEES, 2) complete a historical review of NSF's sustainability efforts in the past 15 years, and 3) review the SEES portfolio solicitations between 2010 to 2014. Final results from this study are expected in FY 2019.

Workshops and Reports:
In 2015, the National Research Council's Ocean Studies board released *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*[1]. This report greatly influenced NSF's Division of Ocean Sciences by addressing the strategic investments necessary to ensure a robust ocean science enterprise and providing guidance on research and infrastructure priorities.

In 2017, the National Academies of Sciences, Engineering, and Medicine's Space Studies Board released an *Assessment of the National Science Foundation's 2015 Geospace Portfolio Review*[2]. This study made recommendations for NSF's implementation of prior recommendations of a portfolio review.

Committees of Visitors (COV):

- In 2016, a COV reviewed the AGS Atmosphere Section. The COV report was presented to the GEO Advisory Committee, which convened in October of 2016. The COV found that the programs under review were well managed, but provided several useful recommendations.
- In 2017, COVs will review programs in EAR and parts of AGS.
- In 2018, COVs will review part of AGS and OCE.

[1]www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences
[2]www.nap.edu/catalog/24666/assessment-of-the-national-science-foundations-2015-geospace-portfolio-review

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 GEO Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	4,680	-	4,400
Other Professionals	2,751	-	2,600
Postdoctoral Associates	590	-	600
Graduate Students	2,330	-	2,200
Undergraduate Students	2,238	-	2,100
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	12,589	-	11,900

DIVISION OF ATMOSPHERIC AND GEOSPACE SCIENCES (AGS) — $227,680,000 / -$25,860,000 / -10.2%

AGS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual: Amount	Change Over FY 2016 Actual: Percent
Total	**$253.54**	**-**	**$227.68**	**-$25.86**	**-10.2%**
Research	**118.94**	**-**	**111.39**	**-7.55**	**-6.3%**
CAREER	5.61	-	5.05	-0.56	-10.0%
Education	**4.41**	**-**	**4.07**	**-0.34**	**-7.7%**
Infrastructure	**130.19**	**-**	**112.22**	**-17.97**	**-13.8%**
Arecibo Observatory	4.10	-	3.82	-0.28	-6.8%
National Center for Atmospheric Research (NCAR)	105.60	-	89.90	-15.70	-14.9%
Research Resources	20.49	-	18.50	-1.99	-9.7%

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, the physics, chemistry, and dynamics of the Earth's atmosphere and near-space environment, and how the sun interacts with the Earth's atmosphere. 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; and the research conducted at facilities provided by the National Center for Atmospheric Research (NCAR), which extends and enhances the capabilities of the research conducted by AGS investigators.

The division focuses on support of fundamental research in the atmospheric and geospace sciences, aimed at improved understanding of all processes that contribute to predictability of weather and climate variability, and with respect to space weather and extreme weather events. Advances in atmospheric and geospace science contribute to and support the development of models for forecasting weather and understanding climate variability, 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. Through improvements to understanding of severe weather events and associated risks, and development of models that simulate and forecast such events, AGS contributes to commerce; the protection of life, property, and natural resources; and the establishment of a weather-ready and space weather-ready Nation. AGS also contributes to STEM education, early career scientists, and the continued development and support of an innovative scientific workforce that contributes to economic vitality and scientific and technological innovation.

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 that supports the capabilities, creativity, and innovation of the atmospheric and geospace science community.

FY 2018 Summary

All funding decreases represent change over the FY 2016 Actual.

Research

- Support for the AGS disciplinary and interdisciplinary research programs decreases by $7.29 million, to a total of $101.56 million, to support basic research into understanding weather and atmospheric variability and extreme atmospheric and space weather phenomena, and improving the fundamentals that lead to better predictability of extreme events.
- AGS will support the NSF Risk and Resilience initiative at a level of $1.50 million through GEO's PREEVENTS activity.
- Investments in the SEES portfolio decrease to zero, concluding the ramping down of the SEES Earth Systems Modeling (EaSM) program.
- Support for early-career researchers remains an AGS priority. The division will support CAREER grants at $5.05 million.

Education

- Education activities across AGS will be supported at a level of $4.07 million, reflecting the division's continuing commitment to the Research Experiences for Undergraduates (REU) program and support for postdoctoral fellows.

Infrastructure

- AGS funding for the Arecibo Observatory will decrease by $280,000, to a total of $3.82 million.
- NCAR support decreases by $15.70 million, to a total of $89.90 million. This decrease will require reassessment and refocusing of priorities for support by NSF and NCAR.
- Research Resources are allocated $18.50 million, a decrease of $1.99 million. Support will be used to enable 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) $161,010,000

-$18,660,000 / -10.4%

EAR Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$179.67**	**-**	**$161.01**	**$18.66**	**10.4%**
Research	**117.48**	**-**	**106.05**	**-11.43**	**-9.7%**
CAREER	7.43	-	6.66	-0.77	-10.4%
Education	**4.14**	**-**	**3.76**	**-0.38**	**-9.2%**
Infrastructure	**58.05**	**-**	**51.20**	**-6.85**	**-11.8%**
Geodesy Advancing Geosciences and EarthScope (GAGE)	11.87	-	10.90	-0.97	-8.2%
Seismological Facilities for the Advancement of Geosciences and EarthScope (SAGE)	24.35	-	22.90	-1.45	-6.0%
Research Resources	21.83	-	17.40	-4.43	-20.3%

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 mineral, water, biota, 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.

In general, 36 percent of the EAR portfolio is available for new research grants and 64 percent is available for continuing grants and the research infrastructure needed by this community

FY 2018 Summary

All funding decreases represent changes over the FY 2016 Actual.

Research

- CAREER funding will be supported at a level of $6.66 million, a decrease of $770,000 million. The reduction is commensurate with the overall decrease for the division, and will result in approximately two fewer CAREER awards in FY 2018.
- EAR will support INFEWS at a level of $1.0 million, a decrease of $720,000.
- Support for Risk and Resilience research will be at $1.50 million, a decrease of $3.25 million. This decrease will be offset by an increase in GEO’s ICER division.

- The FY 2018 Budget Request for disciplinary and interdisciplinary research programs is $95.93 million, a decrease of $6.68 million. This reduction will result in approximately 20 fewer awards in FY 2018.

Education

- EAR's support for education activities will be decreased by $380,000. Research Experiences for Undergraduates (REU) sites will be supported at $1.56 million, a decrease of $170,000. This reduction will result in about one fewer REU site being supported in FY 2018. Support for EAR Postdoctoral Fellowships will continue to be funded at $1.70 million, reflecting EAR's commitment to workforce development.

Infrastructure

- EAR will decrease investment in SAGE (-$1.45 million, to a total of $22.90 million) and GAGE (-$970,000, to a total of $10.90 million). Availability of portable instruments for research and maintenance and upkeep of the facility will decrease.
- Funding of all other research infrastructure at $17.40 million, a decrease of $4.43 million, will require that EAR's Geoinformatics Program fund no new projects in FY 2018 and that the Instrumentation and Facilities Program make no new commitments for instrument acquisition and development in FY 2018.

INTEGRATIVE AND COLLABORATIVE EDUCATION AND RESEARCH (ICER) $71,600,000 -$11,870,000 / -14.2%

ICER Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$83.47**	**-**	**$71.60**	**-$11.87**	**-14.2%**
Research	**52.68**	**-**	**59.90**	**7.22**	**13.7%**
CAREER	0.02	-	-	-0.02	-100.0%
Education	**16.49**	**-**	**11.70**	**-4.79**	**-29.0%**
Infrastructure	**14.30**	**-**	**-**	**-14.30**	**-100.0%**
National Nanotechnology Coordinated Infrastructure	0.30	-	-	-0.30	-100.0%
Ocean Observatories Initiative	14.00	-	-	-14.00	-100.0%

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 2018, the division will make strategic investments in multidisciplinary research areas, international activities, education, diversity, and human resource development. The results of these investments will assist in ensuring that the U.S. has a well-educated and diverse workforce in the geosciences and in related technical fields such as resource exploration. Through investment in Risk and Resilience, ICER will improve predictability and risk assessment in order to increase resilience that will reduce the impact of extreme events on our lives, society, and economy. Research at the Food-Energy-Water nexus will result in understanding interactions across the FEW nexus, how it is likely to affect our world, and how we can proactively plan for its consequences.

In general, 48 percent of the ICER portfolio is available for new research grants and 52 percent is available for continuing grants.

FY 2018 Summary

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

Research

- ICER support for NSF's INFEWS activity increases to $7.0 million. Much of GEO's support for INFEWS is being consolidated in ICER in FY 2018.
- The NSF-wide portfolio for Risk and Resilience research will be supported through GEO's PREEVENTS activity at a level of $13.0 million. Overall GEO support for PREEVENTS remains unchanged.
- ICER support for SEES falls to zero in FY 2018, reflecting the phase-out of this activity.
- ICER supports a varied portfolio of international collaborative activities. In FY 2018, this will total $6.43 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.

Education

- In FY 2018, the ICER education portfolio is decreased by $4.79 million to $11.70 million. ICER supports most of GEO's participation in NSF-wide education programs, many of which are seeing reductions in FY 2018.

Infrastructure

- ICER provided GEO's contribution to the National Nanotechnology Coordinated Infrastructure. GEO support for this activity is being phased out in FY 2018 (-$300,000).
- In FY 2018, ICER will no longer provide support for operation and maintenance for the Ocean Observatories Initiative (OOI). This temporary support, from FY 2015 - 2017, helped 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*,[3] released in January 2015.

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

DIVISION OF OCEAN SCIENCES (OCE) $323,020,000
-$36,810,000 / -10.2%

OCE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$359.83**	**-**	**$323.02**	**-$36.81**	**-10.2%**
Research	**168.34**	**-**	**151.92**	**-16.42**	**-9.8%**
CAREER	3.13	-	2.00	-1.13	-36.1%
Centers Funding (total)	5.00	-	5.00	-	-
STC: Dark Energy Biosphere Investigations	5.00	-	5.00	-	-
Education	**5.30**	**-**	**5.30**	**-**	**-**
Infrastructure	**186.19**	**-**	**165.80**	**-20.39**	**-11.0%**
Academic Research Fleet	82.79	-	77.80	-4.99	-6.0%
International Ocean Discovery Program (IODP)	48.00	-	48.00	-	-
Ocean Observatories Initiative (OCE portion)	40.98	-	31.00	-9.98	-24.4%
Research Resources	11.33	-	9.00	-2.33	-20.6%
Facilities Pre-Construction Planning (total)	3.09	-	-	-3.09	-100.0%
Regional Class Research Vessels (RCRV)	3.09	-	-	-3.09	-100.0%

OCE supports interdisciplinary research and technology, 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 and economic security matters such as sea level rise, ocean storms and influences on weather, and to advance U.S. leadership in ocean science and technology. OCE provides support of basic scientific and technological research to better understand changing ocean circulation and other physical, chemical, and biological parameters. 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 of high societal relevance. Ocean education emphasizes undergraduate REU programs and the interdisciplinary nature of ocean sciences and marine technology, and commonly leverages off research facilities and infrastructure via telepresence to far and distant seas. Since ocean science requires access to the sea, in partnership with the Office of Naval Research and academic institutions, OCE supports research vessels, deep submergence capability including submersibles and autonomous vehicles, and technologically advanced sensors and instrumentation. OCE research, technology, and infrastructure benefits society by advancing our understanding of natural hazards, defining the state of the ocean that contributes to understanding of weather, providing the scientific basis to ocean behavior of relevance to fisheries and aquaculture, and overall addresses the central role of the oceans as a national strategic resource, as recognized by numerous reviews by external bodies (e.g., National Academy of Sciences' Decadal Survey of Ocean Sciences, 2015-2025, *Sea Change*).

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 ongoing awards made in prior years, as well as the major research infrastructure of the Academic Research Fleet, the International Ocean Discovery Program, and the Ocean Observatories Initiative.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- OCE's budget for disciplinary and interdisciplinary research will decrease by $15.96 million, to a total of $132.25 million, which reflects a strategic re-apportioning to continue to support ocean science research and technology programs as per *Sea Change* (National Academy of Sciences, 2015) recommendations.
- In FY 2018, OCE will specifically continue to invest resources into ocean technology via OCE's own programs as well as in coordination with other federal agencies.
- OCE will no longer participate in the Oceans and Human Health program, which was jointly supported with the National Institute of Environmental Health Sciences.

Education

- There is no change in OCE support ($5.30 million) for REU programs and other interdisciplinary education efforts.

Infrastructure

- OCE is decreasing support of ship operations within the Academic Research Fleet by $4.99 million, to a level of $77.8 million, due to the decrease in overall number of vessels, efficiencies gained by technological investment, as well as a fundamental reassessment of the provision of seismic capabilities to the U.S. academic and federal communities. This decrease is consistent with the recommendations from *Sea Change*.
- 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 2018 Request of $48.0 million maintains level funding with no decrease in maintenance and operations per *Sea Change*.
- The total support for operations and maintenance of the Ocean Observatories Initiative (OOI) will be decreased by $9.98 million from OCE, in addition to an end to ICER support, resulting in a total OOI support for operations and management in FY 2018 of $31.0 million. These decreases are strategically oriented to be consistent with the recommendations from the NAS's Decadal Survey, *Sea Change*.
- Preconstruction for the Regional Class Research Vessels (RCRV) concluded in FY 2016 with costs decreasing to zero in FY 2018. For more information on RCRV, see the MREFC chapter.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS)

$1,219,430,000
-$129,350,000 / -9.6%

MPS Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Astronomical Sciences (AST)	$246.63	-	$221.15	-$25.48	-10.3%
Chemistry (CHE)	246.52	-	221.05	-25.47	-10.3%
Materials Research (DMR)	309.88	-	282.87	-27.01	-8.7%
Mathematical Sciences (DMS)	233.95	-	209.78	-24.17	-10.3%
Physics (PHY)	276.91	-	253.30	-23.61	-8.5%
Office of Multidisciplinary Activities (OMA)	34.89	-	31.28	-3.61	-10.3%
Total	**$1,348.78**	**-**	**$1,219.43**	**-$129.35**	**-9.6%**

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. Research in the disciplines supported by MPS has led to advances that are used for a wide variety of applications; examples include laser technology, navigation using the Global Positioning System, materials fundamental to integrated circuits, and algorithms used for advanced cybersecurity. The FY 2018 Budget Request for MPS supports a collection of vigorous disciplinary and multidisciplinary research programs that foster discovery and cultivate the technical workforce. The awards funded by 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 programs in MPS span 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. 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. These multi-directorate activities include growing MPS foundational research for several of the Big Ideas that are discussed elsewhere in this document.

Programs in the MPS divisions respond to special intellectual opportunities and reflect careful choices 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. National Academies input is critical for prioritization; two recent examples are *New Worlds, New Horizons: A Midterm Assessment* (delivered in August 2016) and *Frontiers of Materials Research: A Decadal Survey* (scheduled for completion in FY 2018).

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 collaborations for those facilities.

MPS participates in building the foundation for several of the Big Ideas described previously, in cooperation with many other directorates. In particular, FY 2018 investments will advance the work of two of the Big Ideas.

- DMR and PHY support investments that are important for defining and developing the direction of the Quantum Leap Big Idea. For example, the DMR funding request includes renewal of the Center for Integrated Quantum Materials, while PHY emphasizes investments in Quantum Information Science.
- Both AST and PHY are building the foundation for the Windows on the Universe Big Idea by continuing to invest in large facilities and research awards that make use of information carried by electromagnetic waves, particles, and gravitational waves.

More discussion of these investments and foundation-building for other Big Ideas may be found in the division narratives below as well as in the Facilities chapter.

MPS provides about 49 percent of the federal funding for basic research at academic institutions in the mathematical and physical sciences.

Major Investments

MPS Major Investments

(Dollars in Millions)

Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual: Amount	Change Over FY 2016 Actual: Percent
CAREER	$77.97	-	$71.49	-$6.48	-8.3%
CEMMSS	63.83	-	43.00	-20.83	-32.6%
NSF I-Corps™	1.60	-	1.70	0.10	6.2%
NSF INCLUDES	2.14	-	2.60	0.46	21.5%
NRT[1]	4.47	-	1.00	-3.47	-77.6%
Risk and Resilience	2.31	-	0.50	-1.81	-78.4%
SaTC	1.64	-	1.00	-0.64	-39.0%
SEES	53.47	-	10.42	-43.05	-80.5%
Understanding the Brain	24.13	-	16.56	-7.57	-31.4%
BRAIN Initiative	*24.13*	-	*16.56*	*-7.57*	*-31.4%*

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

All funding decreases/increases represent changes over the FY 2016 Actual.

- Faculty Early Career Development (CAREER) (-$6.48 million to a total of $71.49 million): This will support about 535 awardees. This program remains an MPS priority, ensuring that top early-career scientists in all the MPS disciplines are funded at a healthy level. The CAREER program is an important element in the growth and development of junior scientists.

- Cyber-Enabled Materials Manufacturing and Smart Systems (CEMMSS) (-$20.83 million to a total of $43.0 million): MPS participates in CEMMSS primarily through the Advanced Manufacturing and Materials Genome Initiatives. The Designing Materials to Revolutionize and Engineer our Future (DMREF) program, which contributes to these activities, will not hold a competition in FY 2018.

Rather, DMREF, with its partners in ENG and CISE, will invest in community building activities focused on leveraging the data generated by existing awards to accelerate the discovery and deployment of materials with a specific function or property.

- NSF Innovation Corps (I-Corps™) (+$100,000 to a total of $1.70 million): Investments are directed to an assessment of the commercial viability of the scientific discoveries in MPS disciplines.
- Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) (+$460,000 to a total of $2.60 million): MPS will increase its investment in this program, an NSF-wide broadening participation activity.
- NSF Research Traineeships (NRT) (-$3.47 million to a total of $1.0 million): Funding continues to support the development and implementation of new models for STEM graduate education.
- Risk and Resilience (-$1.81 million to a total of $500,000): This research improves predictive and risk-assessment capabilities and increases resilience to impacts of extreme events on critical infrastructure.
- Secure and Trustworthy Cyberspace (SaTC) (-$640,000 to a total of $1.0 million): Funding reflects continued national need for fundamental cybersecurity research that investigates questions surrounding secure information networks against hostile intrusion and ensuring individual privacy in anonymized data sets.
- Science, Engineering, and Education for Sustainability (SEES) (-$43.05 million to a total of $10.42 million): This investment concluded in FY 2017. Remaining funds will focus on Sustainable Chemistry, Engineering, and Materials (SusChEM) research, supporting commitments made for prior year awards.
- Understanding the Brain (UtB) including the BRAIN Initiative (-$7.57 million to a total of $16.56 million): MPS will continue to invest in the scientific understanding of the full complexity of the brain.

MPS Funding for Centers Programs and Facilities

MPS Funding for Centers Programs

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total, Centers Programs	**$88.43**	**-**	**$91.60**	**$3.17**	**3.6%**
Centers for Analysis & Synthesis (DMS)	0.20	-	-	-0.20	-100.0%
Centers for Chemical Innovation (CHE)	28.10	-	21.60	-6.50	-23.1%
Materials Centers (DMR)	55.54	-	55.00	-0.54	-1.0%
Nanoscale Science & Engineering Centers (CHE, DMR)	0.50	-	-	-0.50	-100.0%
STC: Center for Integrated Quantum Materials (DMR)	4.09	-	5.00	0.91	22.2%
STC: STC for Real-Time Functional Imaging (DMR)	-	-	5.00	5.00	N/A
STC: Center for Bright Beams (PHY)	-	-	5.00	5.00	N/A

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

MPS Funding for Facilities

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Facilities	**$289.42**	**-**	**$291.08**	**$1.66**	**0.6%**
Atacama Millimeter Array (ALMA)	$37.65		$43.48	5.83	15.5%
Arecibo Observatory	4.80	-	3.90	-0.90	-18.8%
Cornell High Energy Synchrotron Source (CHESS)	10.03	-	8.00	-2.03	-20.2%
Daniel K. Inouye Solar Telescope (DKIST)	13.50		16.00	2.50	18.5%
Gemini Observatory	19.88	-	21.03	1.15	5.8%
IceCube Neutrino Observatory (IceCube)	3.48	-	3.50	0.02	0.6%
Large Hadron Collider (LHC)[1]	20.00	-	22.30	2.30	11.5%
Laser Interferometer Gravitational Wave Observatory (LIGO)	39.43	-	39.43	-	-
National High-Magnetic Field Laboratory (NHMFL)	35.34	-	34.77	-0.57	-1.6%
Natiional Nanotechnology Coordinated Infrastructure (NNCI)	2.88	-	2.50	-0.38	-13.2%
National Optical Astronomy Observatories (NOAO)	21.99	-	20.67	-1.32	-6.0%
National Radio Astronomy Observatories (NRAO)[2]	43.84	-	32.86	-10.98	-25.0%
National Solar Observatory (NSO)[3]	9.50	-	5.00	-4.50	-47.4%
National Superconducting Cyclotron Laboratory (NSCL)	24.00	-	23.00	-1.00	-4.2%
Other MPS Facilities (Total)	3.10	-	14.64	11.54	372.3%
Center for High Resolution Neutron Scattering (CHRNS)	2.77	-	2.79	0.02	0.7%
Other Astronomical Facilities (LBO, GBO)[2]	-	-	11.85	11.85	N/A
OMA co-funding of special activities in facilities	0.33	-	-	-0.33	-100.0%

[1] Includes $6.30 million in FY 2018 for High-Lumosity LHC Upgrade planning.

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

[3] Totals do not include $11.50 million in FY 2016 and $14.0 million in FY 2018 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented on the DKIST line above.

For detailed information on individual facilities, see the Facilities and the Major Research Equipment and Facilities Construction chapters.

Funding Profile

MPS supports investment in core research, education, and research infrastructure.

In FY 2018, the number of research grant proposals is expected to increase by over 500 as compared to FY 2016. This expected increase reflects a general upward trend in numbers of research proposals received in recent years. Of this total, MPS expects to award about 1,800 research grants. Average annual award size and duration are not expected to materially fluctuate in FY 2018.

In FY 2018, MPS will invest $91.60 million for centers, accounting for 7.5 percent of the MPS budget. This increase is due to the initiation of two new Science and Technology Centers. Several centers, including Centers for Analysis and Synthesis and the Nanoscale Science and Engineering Centers, have sunset as planned. MPS will continue to support the Materials Centers and the Centers for Chemical Innovation.

Operations and maintenance funding for MPS-supported user facilities is 23.9 percent of MPS's FY 2018 Request. Funding is maintained for most facilities in order to keep operational capacity current. Information about specific funding decreases may be found in the division narratives that follow.

MPS Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	9,203	-	9,900
Number of New Awards	2,436	-	2,300
Funding Rate	26%	-	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	7,979	-	8,500
Number of Research Grants	1,930	-	1,800
Funding Rate	24%	-	21%
Median Annualized Award Size	$122,100	-	$120,000
Average Annualized Award Size	$142,500	-	$140,000
Average Award Duration, in years	3.2	-	3.2

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- The Astronomy and Astrophysics Advisory Committee (AAAC) completed its annual report[1] on interagency activities by the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and NSF in March 2017. The next annual report is expected in March 2018.
- AST, together with the NASA Astrophysics Division and the High Energy Physics Branch of the DOE Office of Science, commissioned a study ("Review of Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics"), 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 report was published in August 2016.[2]
- In FY 2017, the MPS/CHE/Centers for Chemical Innovation (CCI) program will initiate an evaluation of the CCI program. Results are expected to inform CHE regarding program effectiveness and to establish best practices. Final study results expected in late FY 2018 or early FY 2019.
- DMR co-sponsored with the DOE Office of Basic Energy Sciences (BES) a NAS Decadal Survey entitled *Frontiers of Materials Research*. This important study will identify future needs and important emerging research areas of materials research in the context of U.S. and international efforts.[3] A report is anticipated in June 2018 which will inform DMR of future directions.

Workshops and Reports:

- In October 2016, CHE-sponsored a workshop titled "Measuring the Brain: From the Synapse to Thought". The goal was to bring together chemical and neuroscience communities to better understand the intersection of their needs and opportunities. The discussion focused on identifying challenges in brain research for the next decade and how chemical probes, sensors, and measurements could address challenges in understanding brain functioning. A report is expected in late FY 2017.
- CHE sponsored two workshops on opportunities for mid-scale investment. The "Workshop for Mid-Scale Instrumentation in the Chemical Sciences" was held in September 2016 and identified research areas where scientific progress in chemistry is limited or inhibited by a lack of access to mid-scale instrumentation. The "Workshop on Mid-Scale Instrument Development in the Chemical Sciences"

[1] www.nsf.gov/mps/ast/aaac.jsp
[2] http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_161177
[3] http://sites.nationalacademies.org/DEPS/materials-decadal/index.htm

was held in November 2016 and focused on the development of new instrument development capabilities. Reports from both workshops are expected by summer 2017.

- The CHE workshop "Quantum Information and Computation for Chemistry" was held in November 2016, with representatives attending from the chemical community, the NAS, multiple federal agencies, and industries involved in quantum sciences (e.g., Google, Microsoft, and Intel). The workshop summarized recent progress at the interface of quantum information science and chemistry and explored promising research opportunities for chemists in quantum sensing, communication, computers, and computing. A report is expected in late FY 2017.
- The workshop "Framing the Role of Big Data and Modern Data Science in Chemistry" was held in April 2017 and focused on big data research and the use of modern data science in chemistry. The workshop addressed the needs of the chemical research and data science communities to fully develop sharing, searching, and repurposing, for data mining, machine learning, and data analytics.
- DMR sponsored several workshops in FY 2016 and FY 2017 focused on advancing the use of data-driven research in the DMREF program[4], grand challenges in soft condensed matter physics[5,6], emerging trends in topological phases of matter research[7], challenges for young condensed matter physics investigators[8], and new mid-scale tools to advance biomaterials[9] and quantum materials[10].
- DMR supported two major topical program reviews in FY 2016; a decadal survey for polymer science[11] and a four-year review of emerging fundamental science trends in ceramics[12].
- DMR plans to sponsor several workshops throughout FY 2017 and FY 2018 which will focus on condensed matter science, quantum materials[13], mid-scale instrumentation, solid state materials chemistry, electronic and photonic materials, and the application of data-driven science and machine learning to accelerated materials discovery.
- DMS, BIO/IOS, and BIO/MCB sponsored a workshop on *Deciphering Genome to Phenome Relationships: Interdisciplinary Research at the Interface of the Biological and Mathematical Sciences*[14] in October 2015. The findings of the workshop recommended the development of a joint initiative to support research centers on the Mathematics of Complex Biological Systems.
- In April 2016, DMS and CISE/CCF sponsored the workshop "Theoretical Foundations of Data Science (TFoDS): Algorithmic, Mathematical, and Statistical"[15]. Findings led to a FY 2017 joint program for the development of small collaborative institutes on Transdisciplinary Research in Principles of Data Science (TRIPODS) by DMS and CISE/CCF.
- In collaboration with the National Institutes of Health (NIH), DMS supported a Data Science Innovation Lab workshop focused on Interdisciplinary Approaches to Biomedical Data Science in June 2016. The activity brought together researchers in quantitative and biomedical sciences with a goal of developing new research teams to work on problems in biomedical data science. A program solicitation *Joint NSF/NIH Initiative on Quantitative Approaches to Biomedical Big Data (QuBBD)* was issued to encourage proposals for inter- and multi-disciplinary collaborations that focus on innovative and transformative approaches to address challenges in this topic area.
- DMS made an award "GROW: Strengthening the Mathematical Workforce" to support two related conferences aimed at addressing gender imbalances within the mathematical sciences. The first of the

[4] www.orau.gov/mgi2016/
[5] https://mrsec.uchicago.edu/events/grand-challenges-soft-matter-experiment
[6] https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.89.025002
[7] http://scholar.princeton.edu/nsfcmp
[8] http://reg.conferences.dce.ufl.edu/Physics/1202
[9] www.biomatworkshop.org/home.html
[10] http://sites.krieger.jhu.edu/miqm/
[11] https://sites.google.com/a/umn.edu/nsf-polymer-workshop/
[12] http://faber.caltech.edu/nsf/
[13] https://sites.google.com/harvard.edu/nsfquantumrev
[14] www.nsf.gov/mps/dms/documents/Deciphering_Genome-to-Phenome_Relationships.pdf
[15] www.cs.rpi.edu/TFoDS/

conferences was held in October 2016 and the second will be held in October 2017. In view of this, DMS and EHR will be encouraging proposals that would improve and support student transition to and subsequent success in doctoral programs in the mathematical sciences.

Committees of Visitors (COV):
- In FY 2016, COVs reviewed CHE and DMS. The MPS Advisory Committee subsequently accepted both reports.
- In FY 2018, a COV will review PHY.
- In FY 2019, COVs will review AST and DMR.

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

Number of People Involved in MPS Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	8,600	-	8,000
Other Professionals	3,200	-	2,900
Postdoctoral Associates	1,900	-	1,700
Graduate Students	8,200	-	8,000
Undergraduate Students	5,200	-	4,000
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	27,100	-	24,600

DIVISION OF ASTRONOMICAL SCIENCES (AST)

$221,152,000
-$25,480,000 / -10.3%

AST Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$246.63**	**-**	**$221.15**	**-$25.48**	**-10.3%**
Research	**60.72**	**-**	**51.76**	**-8.96**	**-14.8%**
CAREER	4.63	-	4.17	-0.46	-9.9%
Education	**5.90**	-	**5.40**	**-0.50**	**-8.5%**
Infrastructure	**180.01**	-	**163.99**	**-16.02**	**-8.9%**
Arecibo Observatory	4.80	-	3.90	-0.90	-18.8%
Atacama Large Millimeter Array (ALMA)	37.65	-	43.48	5.83	15.5%
Daniel K. Inouye Solar Telescope (DKIST)	13.50	-	16.00	2.50	18.5%
Gemini Observatory	19.88	-	21.03	1.15	5.8%
National Optical Astronomy Observatory (NOAO)	21.99	-	20.67	-1.32	-6.0%
National Radio Astronomy Observatory (NRAO)[1]	41.73	-	32.86	-8.87	-21.3%
National Solar Observatory (NSO)[2]	9.50	-	5.00	-4.50	-47.4%
Other Astronomical Facilities	-	-	11.85	11.85	N/A
Mid-Scale Innovations Program (MSIP)	21.25	-	6.00	-15.25	-71.8%
Research Resources	9.71	-	3.20	-6.51	-67.0%

[1] The decrease in NRAO is chiefly due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMO, starting in FY 2017. That funding is now shown under the "Other Astronomical Facilities" line in this table.
[2] Totals do not include $11.50 million in FY 2016 and $14.0 million in FY 2018 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented on the DKIST line above.

AST is the federal steward for ground-based astronomy in the United States, funding research with awards to individual investigators and small research groups, and supporting operations of large telescope facilities via cooperative agreements. 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, about 28 percent of the AST portfolio is available for new research. About 61 percent of AST's budget supports the forefront instrumentation and facilities needed for progress at the frontiers of observational astronomy, while almost 20 percent supports the research of individual investigators. Through the MREFC appropriation, AST also oversees the construction of LSST and DKIST.

FY 2018 Summary

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

Research
- CAREER (-$460,000 to a total of $4.17 million): This level continues AST's commitment to early-career investigators and will support about 35 awards.
- Disciplinary and interdisciplinary research programs (-$8.68 million to a total of $44.03 million): Support for fundamental research is a major focus. This level will continue support for the Astronomy and Astrophysics Research Grants and Solar and Planetary Grants programs but at a lower level.

Education
- Partnerships in Astronomy and Astrophysics Research and Education (PAARE) (-$500,000 to a total of $1.0 million): Reduced proposal demand in FY 2016 has resulted in a shift in the funding balance between PAARE and other workforce development and early-career programs.

Infrastructure
- ALMA (+$5.83 million to a total of $43.48 million): As ALMA approaches steady state operations, funding includes an increase of the annual contribution to the ALMA Development Fund and long-term maintenance budget as agreed to by the international partners.
- Arecibo Observatory (-$900,000 to a total of $3.90 million): The FY 2016 Actual includes $700,000 in forward funding. The $200,000 balance of the reduction is consistent with the proposed divestment amount appearing in the FY 2017 Arecibo management solicitation.
- DKIST (+$2.50 million to a total of $16.0 million): This supports the continued ramp-up of DKIST operations within NSO to $14.0 million, plus the DKIST cultural mitigation award held steady at $2.0 million. See the Major Research Equipment and Facilities Construction chapter for more detail.
- Gemini Observatory (+$1.15 million to a total of $21.03 million): This supports a slight increase in operations and the instrument development fund as agreed to by the international Gemini Board.
- NOAO (-$1.32 million to a total of $20.67 million): This supports operations of NOAO's optical telescope and data science programs.
- NRAO (-$8.87 million to a total of $32.86 million): This decrease is due to the removal of the Green Bank Observatory 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.
- NSO (-$4.50 million to a total of $5.0 million): Of the total change, most (-$2.50 million to zero) is due to the end of a one-time activity in FY 2016 to make NSO Space Weather infrastructure more robust, and the rest (-$2.0 million, to a total of $5.0 million) is a decrease in NSO base support with the divestment of facilities on Sacramento Peak and Kitt Peak and with emphasis shifting to DKIST operations.
- Other Astronomical Facilities (+$11.85 million to a total of $11.85 million): This funds operational support for GBO and VLBA (now operated by the Long Baseline Observatory), which were moved from the NRAO base budget as noted in the NRAO bullet above.
- Mid-Scale Innovations Program (MSIP) (-$15.25 million to a total of $6.0 million): Of the total change, -$13.25 million results from re-balancing MSIP with core individual investigator programs, but with lower priority given to MSIP while maintaining a minimal level for the program. The $2.0 million balance of the reduction is due to a technical adjustment to recategorize funding for the Dark Energy Survey Data Management within Research Resources below.
- Research Resources (-$6.51 million to a total of $3.20 million): This includes a reduction of $250,000 after 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 are the Advanced Technologies and Instrumentation (ATI) program, which is minimally maintained and to be offered in alternating years, and the Dark Energy Survey Data Management, which remains constant at $2.0 million.

DIVISION OF CHEMISTRY (CHE)

$221,050,000
-$25,470,000 / -10.3%

CHE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$246.52**	**-**	**$221.05**	**-$25.47**	**-10.3%**
Research	**232.49**	**-**	**213.95**	**-18.54**	**-8.0%**
CAREER	26.66	-	23.99	-2.67	-10.0%
Centers Funding (total)	28.35	-	21.60	-6.75	-23.8%
Centers for Chemical Innovation	28.10	-	21.60	-6.50	-23.1%
Nanoscale Science & Engineering Centers	0.25	-	-	-0.25	-100.0%
Education	**6.47**	**-**	**2.40**	**-4.07**	**-62.9%**
Infrastructure	**7.56**	**-**	**4.70**	**-2.86**	**-37.8%**
National High Magnetic Field Laboratory (NHMFL)	1.92	-	1.73	-0.19	-9.9%
National Nanotechnology Coordinated Infrastructure (NNCI)	0.30	-	-	-0.30	-100.0%
Research Resources	5.34	-	2.97	-2.37	-44.4%

CHE supports a large and vibrant research community engaged in fundamental discovery, invention, and innovation in the chemical sciences. CHE enables research in the theoretical, computational, and experimental design, synthesis, and characterization of new molecules, surfaces, and nanostructures often leading to commercial products which benefit society. The division provides new tools for chemical discovery, including those in data discovery science where increasing volumes and varieties of data are harnessed to advance discovery and innovation. CHE solves gaps in our knowledge of the fundamental rules of life in terms of determining structure-function relationships in biological systems. CHE researchers contribute to the production of next generation technologies for sensing, computing, modeling, and communicating at the quantum level by observing, manipulating, and controlling the behavior of particles and energy in nanometer dimensions. The division is also involved in the development of new tools to examine and solve complex chemical problems including the synergistic combination of multiple types of measurements (including remote access and cyber-enabled tools) and the development of de novo instruments. CHE supports curiosity-driven research that leads to increased understanding of molecules and their chemical transformations, that are often manifest in the chemical, agricultural, and pharmaceutical industries. The division also supports the development of new instrumentation to study and detect molecules important for sensing, monitoring, understanding, and improving the sustainability of chemical reactions at both the lab bench and commercial scales.

In general, 61 percent of the CHE portfolio is available for new research grants and 39 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CAREER grants (-$2.67 million to a total of $23.99 million) are funded at a rate equal to general unsolicited research grants. This is consistent with the CHE objectives of encouraging broadening participation and education while focusing on the frontiers of the field. This will fund about 90 awards.
- Disciplinary and Interdisciplinary Research (-$9.04 million to a total of $163.79 million): Support for

fundamental research is the core mission of CHE. Funding changes include:

- Research at the Interface of the Biological, Mathematical and Physical Sciences (BioMaPS) (-$5.70 million to a total of $1.90 million) was widely embraced by the CHE community and will be mainstreamed into core programs. CHE will only support remaining continuing grant increments (CGIs) in FY 2018. CHE continues to support efforts at the chemistry-biology interface in activities such as the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative (level at a total of $5.76 million) as well as an examination of the rules of life, which focus on structure-function relationships related to biological systems.
- Some programs are scheduled to sunset as activity moves from special investments to core research programs. Continuing grant increments at FY 2018 Request for SEES include Sustainable Chemistry, Engineering and Materials (SusChEM, -$31.28 million to a total of $10.42 million).
- Designing Materials to Revolutionize and Engineer our Future (DMREF) program (-$3.0 million to zero) will not issue a solicitation in FY 2018. Instead, CHE will focus on engaging the community in data-driven discovery science which seeks to emphasize the effective sharing, mining, and repurposing of rapidly-growing chemical datasets and to apply state-of-the-art data analytics tools to expand chemical understanding.

- The Centers for Chemical Innovation (CCI) program (-$6.50 million to a total of $21.60 million) makes two levels of awards: Phase I for center development, and Phase II for full centers. Phase I awards are considered part of CHE's D&IR investments. In FY 2018, CHE will support six Phase II Centers (two have sunset since FY 2016) at a reduced level relative to the standard center award. The CCI program continues the exploration of major, long-term research challenges, producing transformative research that leads to innovation and attracts broad scientific and public interest.
- Nanoscale Science and Engineering Centers (-$250,000 to zero): This program will sunset as planned in FY 2017.

Education

- CHE contributes to a number of education and diversity activities: Research Experiences for Undergraduates (REU) support totals $2.35 million (-$3.28 million); success rates for REU Sites is projected to be similar to proposals submitted to core research programs. Support is level at $50,000 in total for Research Experiences for Teachers (RET) and Career Life Balance (CLB) and level at $330,000 for Alliances for Graduate Education and the Professoriate (AGEP).

Infrastructure

- NHMFL, specifically the Ion Cyclotron Resonance (ICR) facility (-$190,000 to a total of $1.73 million): The decrease is consistent with the decrease in chemistry-focused research at the facility.
- NNCI (-$300,000 to zero): Nanochemistry investments are well supported within our core programs as demonstrated by the National Nanotechnology Initiative (NNI, level at $47.94 million).
- Research Resources (-$2.37 million to a total of $2.97 million): Support includes the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCRS) at Argonne National Laboratory (level at $970,000) and adds support for highly meritorious Materials Research Instrumentation (MRI) proposals (-$2.37 million to a total of $2.0 million).

DIVISION OF MATERIALS RESEARCH (DMR) $282,870,000

-$27,010,000 / -8.7%

DMR Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$309.88**	**-**	**$282.87**	**-$27.01**	**-8.7%**
Research	**238.28**	**-**	**227.12**	**-11.16**	**-4.7%**
CAREER	24.06	-	24.03	-0.03	-0.1%
Centers Funding (total)	59.88	-	65.00	5.12	8.6%
Materials Research Science & Engineering Centers	55.54	-	55.00	-0.54	-1.0%
Nanoscale Science & Engineering Centers	0.25	-	-	-0.25	-100.0%
STC: Center for Integrated Quantum Materials	4.09	-	5.00	0.91	22.2%
STC: Science and Technology Center on Real-Time Functional Imaging	-	-	5.00	5.00	N/A
Education	**5.79**	**-**	**2.00**	**-3.79**	**-65.4%**
Infrastructure	**65.82**	**-**	**53.75**	**-12.07**	**-18.3%**
Cornell High Energy Synchrotron Source (CHESS)	10.03	-	8.00	-2.03	-20.3%
National High Magnetic Field Laboratory (NHMFL)	33.42	-	33.04	-0.38	-1.1%
Nat'l NanotechnologyCoordinated Infrastructure (NNCI)	2.58	-	2.50	-0.08	-3.1%
Mid-scale Research Infrastructure	15.28		6.09	-9.19	-60.1%
Research Resources[1]	1.73		1.33	-0.40	-23.2%
Center for High Resolution Neutron Scattering (CHRNS)	2.77	-	2.79	0.02	0.7%

[1] Includes investments in materials instrumentation. Higher funding in FY 2016 is attributed to one additional instrumentation award.

DMR invests in the discovery of new materials and the explanation of materials phenomena. Materials are ubiquitous and pervasive, serving as the critical building block to modern technology and innovation. DMR accomplishes its goal by support of basic experimental and theoretical research through a range of programs focused 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.

The discovery and deployment of new materials have shaped our understanding of our world and enabled significant advances in electronics, communications, transportation, and health-related fields. The health of this enterprise is dependent on investments across scales; from single investigators to teams and centers; to singularly focused discipline research versus that requiring interdisciplinarity; and small instruments to large-scale facilities.

In general, 34 percent of the DMR portfolio is available for new research grants and 66 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CAREER ($24.03 million, no change): DMR places a high priority on developing the pipeline of new faculty in materials research who will help form the future community. This supports about 180 awards.
- Disciplinary and Interdisciplinary Research (-$16.53 million to a total of $133.10 million): Support for fundamental research is the core mission of DMR. Funding changes include:

  - CEMMSS (-$10.88 million to a total of $14.67 million): DMR participates in CEMMSS through the Advanced Manufacturing and Materials Genome Initiatives. Programs that contribute to these initiatives are DMREF, MIP (see Research Infrastructure below), the Scalable Nanomanufacturing solicitation, and Materials Research Science and Engineering Centers, and core program investments. There will not be a DMREF (-$8.97 million for a total of $5.0 million) competition in FY 2018. DMR, along with program partners in ENG, CISE, and other MPS divisions, will invest in community building activities focused on leveraging the data generated by these awards to accelerate the discovery and deployment of materials with a specific function or property through synergistic integration of theory/computation, experiments, and systematic use of materials data.
- Materials Research Science and Engineering Centers (MRSECs) (-$540,000 to a total of $55.0 million): MRSECs advance materials research through collaborations of groups of principal investigators and provide students with a rich interdisciplinary education, while addressing fundamental research problems at the forefront of the field. The long-standing, flagship program will complete its triennial competition in FY 2017. In FY 2018, about 20 new and continuing awards are expected.
- Science and Technology Centers (+$5.91 million to a total $10.0 million): Funding reflects the prospective renewal of the Center for Integrated Quantum Materials, which explores the fundamental science of quantum materials and quantum devices, and ramp up support for the new STC on Real-Time Functional Imaging, initiated in FY 2016 to integrate different imaging modalities using electron, X-ray, optical, and nano-probe microscopies to tackle major scientific challenges with broader impacts to manufacturing quality control, medical diagnostics, and airport security.
- Nanoscale Science and Engineering Centers (-$250,000 to zero): This program will sunset as planned in FY 2017.

<u>Education</u>

- Research Experiences for Undergraduates (REU) Sites (-$3.12 million to a total of $2.0 million): DMR remains committed to supporting the next generation of scientists and engineers. This reduced level will allow for the renewal of the most productive REU sites. Further, DMR infrastructure programs, such as centers (MRSEC and PREM) and facilities (NHMFL, CHRNS, CHESS, and MIP), provide significant REU opportunities for undergraduates across the U.S.

<u>Infrastructure</u>

- CHESS (-$2.03 million to a total of $8.0 million): CHESS, as a high-energy X-ray national user facility, serves researchers in fields of biology, engineering, and materials. The FY Budget 2018 Request is consistent with plans to transition the facility from NSF stewardship to a partnership model, which will begin ahead of schedule in FY 2018.
- NHMFL (-$380,000 to a total of $33.04 million): The world leading NHMFL is the only U.S. facility that provides extremely high magnetic fields, enabling transformative research in disciplines ranging from biology and chemistry to materials and condensed matter physics. NHMFL remains a high divisional priority.
- Mid-scale Research Infrastructure program (MIP) (-$9.19 million to a total of $6.09 million): DMR awarded the first class of MIPs in FY 2016. MIPs embrace the goals set forth by the Materials Genome Initiative, including a focus on data-driven accelerated research, and the inaugural class is focused on the discovery of new 2D materials for advanced electronics. The planned FY 2018 competition is postponed until the next focus topic is identified; the FY 2018 Request funds the operations costs only for the class of 2016 MIPs.
- Research Resources (-$400,000 to a total of $1.33 million): This supports liquid helium and liquid helium recovery systems, the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCARS), and instrumentation for materials research. One additional instrumentation award was made in FY 2016, which is not anticipated in FY 2018.

DIVISION OF MATHEMATICAL SCIENCES (DMS) $209,780,000
-$24,170,000 / -10.3%

DMS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$233.95**	**-**	**$209.78**	**-$24.17**	**-10.3%**
Research	**222.09**	**-**	**199.28**	**-22.81**	**-10.3%**
CAREER	14.07	-	12.00	-2.07	-14.7%
Centers Funding (total)	0.20	-	-		-
Centers for Analysis & Synthesis	0.20	-	-	-0.20	-100.0%
Education	**11.86**	**-**	**10.50**	**-1.36**	**-11.5%**

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 joint activities in biosciences with the National Institutes of Health, joint activities in threat detection/data science with the National Geospatial-Intelligence Agency, a program for the development of small collaborative institutes on Transdisciplinary Research in Principles of Data Science with CISE/CCF as well as an initiative to support research centers on the Mathematics of Complex Biological Systems with BIO.

In general, 47 percent of the DMS portfolio is available for new research grants and 53 percent is available for continuing grants.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CAREER (-$2.07 million to a total of $12.0 million): Support for early-career researchers is a division priority. This level supports about 170 awards.
- Centers for Analysis and Synthesis (-$200,000 to zero): DMS contribution to the National Institute for Mathematical and Biological Synthesis (NIMBioS) ends as planned in FY 2017.
- Disciplinary and Interdisciplinary Research (-$20.80 million to a total of $182.39 million): Support for fundamental research is the core mission of DMS. Funding changes include:

- Critical Techniques, Technologies and Methodologies for Advancing Foundations and Applications of Big Data Sciences and Engineering (BIGDATA) (-$2.0 million to zero): DMS will realign its investment amid new DMS activities in data science.
- Research at the Interface of the Biological, Mathematical and Physical Sciences, and Engineering (BioMaPS) (-$3.26 million to zero): DMS will realign its investment into new DMS activities in life sciences.
- DMREF (-$1.50 million to zero): DMS will continue to support 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 through disciplinary programs.
- Mathematical Sciences Innovation Incubator (MSII) (-$2.0 million to zero): DMS will put this new program on hold.
- Mathematical Sciences Research Institutes (-$3.10 million to a total of $25.80 million): Six DMS-supported institutes will continue to catalyze frontier research through an array of scientific programs. DMS will maintain the level of support for the development of small collaborative institutes on Transdisciplinary Research in Principles of Data Science. DMS will start supporting research centers on the Mathematics of Complex Biological Systems jointly with the Directorate for Biological Sciences.
- Optics and Photonics (-$1.50 million to zero): Fundamental research in optics and photonics will be supported by DMS disciplinary programs.
- Secure and Trustworthy Cyberspace (SaTC) (-$1.0 million to a total of $1.0 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.
- Understanding the Brain (UtB) (-$1.54 million to a total of $3.0 million): DMS will support investments into scientific understanding of the full complexity of the brain cross-disciplinary investments.
- Workforce Program in the Mathematical Sciences (-$4.0 million to a total of $18.0 million): DMS will put on hold the relatively new Enriched Doctoral Training in the Mathematical Sciences program.

Education

- Research Experiences for Undergraduates (REU) (-$1.36 million to $4.50 million): DMS maintains a commitment to REU Sites and REU Supplements activities.
- Mathematical Sciences Postdoctoral Research Fellowships (MSPRF) (level at $6.0 million). Investments continue in a number of education and diversity activities through the program.

DIVISION OF PHYSICS (PHY) $253,300,000 -$23,610,000/ -8.5%

PHY Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$276.91**	-	**$253.30**	**-$23.61**	**-8.5%**
Research	**174.12**	-	**152.09**	**-22.03**	**-12.7%**
CAREER	8.12	-	7.30	-0.82	-10.1%
STC: Center for Bright Beams (CBB)	-	-	5.00	5.00	N/A
Education	**5.40**	-	**4.80**	**-0.60**	**-11.1%**
Infrastructure	**97.39**	**-**	**96.41**	**-0.98**	**-1.0%**
IceCube	3.48	-	3.50	0.02	0.6%
Large Hadron Collider (LHC)	20.00	-	16.00	-4.00	-20.0%
Laser Interferometer Gravitational Wave Observatory (LIGO)	39.43	-	39.43	-	-
Nat'l Superconducting Cyclotron Lab. (NSCL)	24.00	-	23.00	-1.00	-4.2%
Midscale Research Infrastructure	10.48	-	8.18	-2.30	-21.9%
Pre-construction planning:	-	-	6.30	6.30	N/A
High-Luminosity LHC Upgrade Planning	-	-	6.30	6.30	N/A

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 United States 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.

Research in physics is invariably accompanied by the development of new analytical, computational, and technological approaches, many of which then go on to have major impact in other scientific and engineering fields. These include, for example: advances in ways to move, analyze, and store large data sets that are directly related to the data revolution; advances in understanding of quantum mechanics that underpin the development of a spectrum of quantum technologies that influence communication, computation, and sensing; and the search for theoretical concepts that could provide guidance to understanding how and why cancer develops.

In general, about 20 percent of the PHY portfolio is available for new research grants. The remaining 80 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 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- CAREER (-$820,000 to a total of $7.30 million): This level preserves the percentage of CAREER awards as a fraction of the overall D&IR budget and will support roughly 60 awards.
- Disciplinary and Interdisciplinary Research (-$25.56 million to a total of $135.53 million): Funding will retain emphasis on investments in Quantum Information Science and computational needs for addressing large data sets and in NSF-wide investments such as:
  - UtB (-$1.75 million to a total of $4.0 million): This provides continued support for physics-based research that enables scientific understanding of the full complexity of the brain, in action and in context.
- Science and Technology Center: Center for Bright Beams (+$5.0 million to a total of $5.0 million): Funding will ramp up as planned for this Class of 2016 cohort.

Education

- REU (-$570,000 million to $4.70 million): This level preserves the percentage of funding for the REU program as a fraction of the overall D&IR budget.

Infrastructure

- IceCube (+$20,000 to a total of $3.50 million): This reflects the funding profile developed under the new cooperative agreement initiated in FY 2016.
- LHC (-$4.0 million to a total of $16.0 million): This supports operations of the ATLAS and CMS detectors at LHC. The decrease is due to the redirection of funds to planning for the High-Luminosity LHC Upgrade as described below.
- 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 (-$1.0 million to a total of $23.0 million): This supports operations of NSCL at Michigan State University. This will result in fewer operating hours, but is consistent with prior funding levels..
- Mid-scale Research Infrastructure (-$2.30 million to a total of $8.18 million): Funding will support the continuation of projects started in previous years. The decrease is due to the redirection of funds to planning for the High-Luminosity LHC Upgrade as described below.
- High-Luminosity LHC Upgrade Planning (+$6.30 million to a total of $6.30 million): This added funding will allow development and planning that could possibly lead to a major construction upgrade of the ATLAS and CMS detectors at LHC beginning in FY 2020.

OFFICE OF MULTIDISCIPLINARY ACTIVITIES (OMA) $31,280,000
-$3,610,000 / -10.3%

OMA Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$34.89**	-	**$31.28**	**-$3.61**	**-10.3%**
Research	**21.24**	-	**20.18**	**-1.06**	**-5.0%**
CAREER	0.42	-	-	-0.42	-100.0%
Education	**7.02**	-	**4.10**	**-2.92**	**-41.6%**
Infrastructure	**6.63**	-	**7.00**	**0.37**	**5.6%**

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 undertaken by multi-investigator, multidisciplinary teams, as well as cross-NSF and interagency activities.

In FY 2018, OMA will focus on multidisciplinary research, chiefly through grant co-funding with MPS Divisions, that advance the basic foundations of mathematical and physical sciences. An important scientific focus for OMA investment in FY 2018 will be the area of quantum information science, where NSF participation in the form of sponsored projects could provide the impetus to advance both science and technology in a disruptive manner. This investment is expected to involve several divisions within MPS as well as within ENG and CISE. This investment also has the potential for significant societal benefit, as it offers approaches that move past the limitations of silicon technology. OMA also will provide leadership and support for I-Corps™, INCLUDES, and NSF Research Traineeships (NRT) activities within MPS. Beginning in FY 2016 and continuing through at least FY 2018, OMA purposefully invests, in partnership with the disciplinary programs that comprise the MPS Directorate, in grants to PIs at HBCUs to build capacity. Finally, in FY 2018, OMA will continue to invest generously in supplements that are designed to engage students from historically underrepresented racial and ethnic groups through graduate research supplements to projects at institutions that have active or legacy awards for the Alliances for Graduate Education and the Professoriate (AGEP-GRS) and Graduate Research Supplements to Veterans (GRSV).

In general, 39 percent of the OMA portfolio is available for new, multidisciplinary research grants within MPS, and 61 percent is available to support research and education activities that are of interest to MPS but that are led by NSF directorates other than MPS.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Research

- Disciplinary and Interdisciplinary Research (+800,000 to a total of $17.90 million): Funding will focus on multidisciplinary research that addresses key MPS and NSF-wide investments such as Quantum Information Science, the Materials Genome Initiative through NSF’s CEMMSS program, Clean Energy, and UtB.

- I-Corps™ (+100,000 to total of $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.

Education

- In FY 2018, OMA will continue to invest on behalf of the entire MPS Directorate in the NRT program (-$3.47 million to $1.0 million).
- Career Life Balance (-$200,000 to $200,000): The decrease in the OMA investment is counterbalanced by a contribution from the sponsoring program or division, resulting in 1:1 funding with OMA.

Infrastructure

- Portfolio analysis (+$370,000 to 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) $244,020,000 -$28,180,000/ -10.4%

SBE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Social and Economic Sciences (SES)	$98.12	-	$87.06	-$11.06	-11.3%
Behavioral and Cognitive Sciences (BCS)	95.01	-	85.32	-9.69	-10.2%
National Center for Science and Engineering Statistics (NCSES)	50.74	-	48.19	-2.55	-5.0%
SBE Office of Multidisciplinary Activities (SMA)	28.32	-	23.45	-4.87	-17.2%
Total	**$272.20**	**-**	**$244.02**	**-$28.18**	**-10.4%**

About SBE

The mission of the Directorate for Social, Behavioral, and Economic Sciences (SBE) is to promote the understanding of people and their lives by supporting research that reveals basic facets of human behavior and social institutions; to encourage research that addresses important societal questions and problems in the national interest; to work with other scientific disciplines to ensure that basic research and solutions to problems build upon the best disciplinary and multidisciplinary science; and to provide mission-critical statistical information about the Science and Engineering (S&E) enterprise in the United States 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. In addition, the directorate combines these disciplinary sciences in interdisciplinary activities linking them to each other and to other science and engineering fields. SBE plays a role as a major partner across the agency due to the relevance of the social, behavioral, and economic sciences in NSF priority investments.

SBE seeks to inspire and invest in the next generation of scientists who will be able to capitalize on the growing availability of massive amounts of different types of data to advance knowledge about human behavior—for example, to use and combine data from surveys, administrative records, brain imaging, and biospecimen analysis as well as output from behavioral, environmental, and geographic sensors. As young scientists embark on their careers, they bring novel and far reaching ideas into play that can transform the future and seed the next harvest of discoveries in the social, behavioral, and economic sciences.

SBE's FY 2018 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, and 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.

SBE's FY 2018 Budget Request 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); the Secure And Trustworthy Cyberspace (SaTC) investment; Risk and Resilience via the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program; Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS); and Harnessing the Data Revolution (HDR), which includes the SBE-managed Resource Implementations for Data Intensive Research in the Social Behavioral and Economic Sciences (RIDIR) program. 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. SBE also continues to support, along with other NSF directorates, research and other activities that enhance the robustness and reliability of research.

Work at the Human-Technology Frontier: Shaping the Future (W-HTF)—SBE will lead the W-HTF Big Idea in partnership with the Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), Education and Human Resources (EHR), and the Office of Integrative Activities (OIA). The W-HTF will engage the research communities in the sciences, engineering, and education to understand and explain how constantly evolving technologies are changing the world of work and the lives of workers and how people can in turn shape those technologies. As part of W-HTF, NSF will continue the visioning and planning activities that began in 2017 with workshops and research coordination networks (RCNs). Together with other directorates, SBE will continue to invest in the foundational basic research and engineering underlying W-HTF, as well as the development and capacity-building of the interdisciplinary communities that will help to advance this area.

SBE provides approximately 68 percent of the federal funding for basic research at U.S. academic institutions in the social, behavioral, and economic sciences.

Major Investments

SBE Major Investments

(Dollars in Millions)

Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
CAREER	$9.50	-	$7.37	-$2.13	-22.4%
Harnessing the Data Revolution	-	-	3.25	3.25	N/A
I-Corps™	0.50	-	0.50	-	-
NSF INCLUDES	0.55	-	0.50	-0.05	-9.1%
INFEWS	4.50	-	2.50	-2.00	-44.4%
Risk and Resilience	4.90	-	2.90	-2.00	-40.8%
SaTC	4.00	-	4.00	-	-
Smart and Connected Communities	1.50	-	1.00	-0.50	-33.3%
Understanding the Brain	26.91	-	24.00	-2.91	-10.8%
BRAIN Initiative	*7.54*	-	*6.17*	*-1.37*	*-18.2%*

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

All funding decreases/increases represent changes over the FY 2016 Actual.

- Faculty Early Career Development (CAREER): SBE supports CAREER (-$2.13 million 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.

- HDR ($3.25 million): SBE's HDR investment will encompass the directorate's existing data-related research and research infrastructure portfolio that is transitioning from the sunsetting CIF21 activity, including RIDIR; Critical Techniques, Technologies and Methodologies for Advancing Foundations and Applications of Big Data Science (BIGDATA); and Data Infrastructure Building Blocks (DIBBs). As part of HDR, SBE will also collaborate with other NSF directorates and offices on new approaches to community data governance and research data lifecycles in alignment with NSF's Public Access Plan.

- I-Corps™: In FY 2018, 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 (-$50,000 to a total of $500,000) in the NSF-wide effort to increase participation of underrepresented groups in STEM fields.

- INFEWS: SBE will continue support (-$2.0 million to a total of $2.50 million) for this NSF-wide initiative 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.

- Risk and Resilience: SBE will provide continued investment (-$2.0 million, to a total of $2.90 million) in Critical Resilient Interdependent Infrastructure Systems and Processes (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 its 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.

- Smart and Connected Communities (S&CC): SBE will continue to fund (-$500,000, to a total of $1.0 million) the S&CC activity. In partnership with CISE and 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 will continue (-$2.91 million, to a total of $24.0 million) support of an integrative and comprehensive understanding of the brain and its function in context and in action. Investments will continue in cognitive science and neuroscience, including the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, as well as 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Centers Programs	**$0.13**	**-**	**-**	**-$0.13**	**-100.0%**
Nanoscale Science & Engineering Centers (SES)[1]	0.13	-	-	-0.13	-100.0%

[1] The Nanoscale Centers program will sunset as planned in FY 2017.

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

Funding for the Nanoscale Science & Engineering Centers (NSEC) ends in FY 2017 as two centers focused on the environmental implications of nanotechnology receive their final year of planned NSF support.

SBE Funding for Facilities

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, Facilities	**$0.40**	**-**	**$0.40**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (SES)	0.40	-	0.40	-	-

SBE continues support for research infrastructure through investment in the National Nanotechnology Coordinated Infrastructure (NNCI), which is unchanged from the FY 2016 level of $400,000.

Funding Profile

SBE supports investments in core research, education, and research infrastructure. SBE will continue to fund research in areas such as UtB, INFEWS, Risk and Resilience, and cybersecurity research, while prioritizing its disciplinary and interdisciplinary investigator-led core research areas.

In FY 2018, the number of research grant proposals is projected to increase slightly relative to FY 2016. As shown in the table below, SBE expects to make approximately 900 new awards. The average annualized award size and award duration are estimated to remain constant with FY 2016.

FY 2018 funding for facilities accounts for less than one percent of SBE's Request and includes support for NNCI.

SBE Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,179	-	4,200
Number of New Awards	993	-	900
Funding Rate	24%	-	21%
Statistics for Research Grants:			
Number of Research Grant Proposals	2,980	-	3,000
Number of Research Grants	638	-	600
Funding Rate	21%	-	20%
Median Annualized Award Size	$116,611	-	$110,000
Average Annualized Award Size	$135,357	-	$135,000
Average Award Duration, in years	2.6	-	2.6

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- In FY 2015, SES awarded funding to support a 15-month examination by a National Academies of Sciences, Engineering, and Medicine (NAS) standing committee of the three major ongoing social science surveys: American National Election Studies (ANES), General Social Survey (GSS), and Panel Study of Income Dynamics (PSID). The objectives are to inform NSF's future efforts of the ANES, GSS, and PSID that enhance their importance and cost-effectiveness. This is especially critical as these three surveys represent considerable infrastructure opportunities and costs for the SBE sciences. The NAS standing committee considered the history of the surveys and the kinds of users and uses they have supported. The Committee's report provided insights about opportunities for collaboration and interoperability among the surveys, with foci on innovation, data collection and data dissemination.
- NCSES convened two review activities under the auspices of the NAS Division of Behavioral and Social Sciences and Education Committee on National Statistics (CNSTAT) to conduct a comprehensive review of the Center's approach to measuring the U.S. S&E enterprise. The first, continuing through FY 2017, examines current approaches to measuring the S&E workforce and will provide 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, convened in FY 2016 on innovation activities and innovation measurement, will inform the refinement and prioritization of NCSES work in innovation planning in FY 2017 and beyond.[1]

Workshops and Reports:

- In order to develop a resource for policy makers in their decision-making and for NSF in its strategic planning process, NSF has requested that NAS convene a committee of experts to produce a report that describes the role of social, behavioral, and economic sciences in helping to address national priorities and to inform decisions about investments at NSF. The committee will be comprised of experts from multiple fields of sciences as well as from business and industry. A prepublication version of the report is expected to be released to the public in early summer 2017; the final report is to be published in late summer 2017.

[1] www.nap.edu/catalog/23640/advancing-concepts-and-models-for-measuring-innovation-proceedings-of-a

Committees of Visitors (COV):

- In 2016 a COV reviewed SES. COV reports and SBE responses were presented to and approved by the SBE Advisory Committee in October, 2016. The SES COV provided input regarding the division's programs and the scientific and management aspects related to the administration of the merit review process, expanding the reviewer pool, best practices for rotating program officers, increasing grant proposals from under-represented institutions, and continuing investments to improve data availability and access with a goal of SES's continued support for NSF efforts to foster robust and reliable science.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate advisory committees. See this chapter for additional information.

Number of People Involved in SBE Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	1,781	-	1,600
Other Professionals	464	-	400
Postdoctoral Associates	198	-	200
Graduate Students	1,554	-	1,400
Undergraduate Students	998	-	900
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	4,995	-	4,500

DIVISION OF SOCIAL AND ECONOMIC SCIENCES (SES) $87,060,000
-$11,060,000 / -11.3%

SES Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$98.12**	**-**	**$87.06**	**-$11.06**	**-11.3%**
Research	**87.02**	**-**	**79.67**	**-7.35**	**-8.4%**
CAREER	3.32	-	3.74	0.42	12.6%
Centers Funding (total)	0.13	-	-	-0.13	-100.0%
Nanoscale Science & Engineering Centers	0.13	-	-	-0.13	-100.0%
Education	**2.84**	**-**	**0.90**	**-1.94**	**-68.3%**
Infrastructure	**8.27**	**-**	**6.49**	**-1.78**	**-21.5%**
NNCI	0.40	-	0.40	-	-
Research Resources	7.87	-	6.09	-1.78	-22.6%

SES supports research and related activities that improve understanding of economic, social, and political 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; and broadening participation in the social, behavioral, and economic sciences. Discipline-based programs include economics, political science, and sociology, while interdisciplinary programs support research in 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 addition, SES research contributes to better understanding of issues related to national security, terrorism, and economic, social, and behavioral well-being.

SES's FY 2018 Budget Request reflects its strong contribution to the unifying themes in the FY 2018 NSF Budget Request by supporting several NSF-wide investments that cross multiple scientific disciplines. This includes 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 funds the 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 2018, SES will maintain investment in the National Nanotechnology Coordinated Infrastructure.

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

FY 2018 Summary

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

Research

- SES will support 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 in FY 2018 is $2.40 million.
- CAREER funding in FY 2017 totals $3.74 million, an increase of $420,000. This investment is consistent with SES's emphasis on supporting early career researchers.
- 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 invest $1.40 million in INFEWS, which will enhance capacity to explore the interactions among water, food, and energy systems.
- SES will invest $500,000 in S&CC. In partnership with ENG, GEO, 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.

Education

- SES will maintain its investment in the NSF-wide effort to increase participation of underrepresented groups in STEM fields through the NSF INCLUDES program at $250,000.
- Support is provided for the ADVANCE program (-$450,000, to a total of $150,000) and Research Experiences for Undergraduates (REU) Supplements (+$200,000, to a total of $500,000), respectively.

Infrastructure

- SES will maintain its investment of $400,000 in NNCI.
- SES research resources activities are funded for a total of $6.09 million (-$1.78 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. In addition, research resources funding includes SES's 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) $85,320,000 -$9,690,000 / -10.2%

BCS Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$95.01**	**-**	**$85.32**	**-$9.69**	**-10.2%**
Research	**90.58**	**-**	**83.83**	**-6.75**	**-7.5%**
CAREER	6.10	-	3.63	-2.47	-40.5%
Education	**2.62**	**-**	**0.79**	**-1.83**	**-69.8%**
Infrastructure	**1.82**	**-**	**0.70**	**-1.12**	**-61.4%**
Research Resources	1.58	-	0.70	-0.88	-55.7%

BCS supports research and related activities that advance fundamental understanding in the behavioral, cognitive, anthropological, neuroscience, and geographic sciences. Strong core programs are complemented by active involvement in competitions that support collaborative and cross-disciplinary projects that increase understanding of mind, brain, culture, and society. 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. 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 anticipate and respond to critical issues in areas such as national security, terrorism, and global change.

As a basic aspect of the leadership provided by BCS in fundamental human neuroscience research and the biological understanding of mind and behavior including genetics research, in FY 2018, BCS will continue to 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 S&CC research area. BCS will invest in the CAREER program, emphasizing the importance of developing scientific intellectual capital for developing leadership and innovation in the U.S.; and in CRISP as part of the Risk and Resilience portfolio. BCS will support behavioral, cognitive, anthropological, and geographic research that deepens understanding of basic scientific questions that inform critical issues facing the Nation, such as threats to national security and terrorism, pandemics, sustainability, and forensic science. In all activities, BCS continues to support an interdisciplinary approach to science, 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 and enhancements in 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, emotion, social interaction, and behavior through various research mechanisms.

In general, 80 percent of the BCS portfolio is available for new research grants and 20 percent is available for continuing grants.

FY 2018 Summary

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

Research

- Support of $17.60 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 provide $500,000, 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 2018 totals $3.63 million, a decrease of $2.47 million. This investment is consistent with BCS's emphasis on supporting early career researchers.
- 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 $1.10 million in INFEWS. This investment will enhance capacity to explore the interactions among water, food, and energy systems.
- BCS will fund an investment of $500,000 in S&CC. In partnership with ENG, GEO 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 Science of Broadening Participation 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.

Education

- BCS support for the ADVANCE program is $100,000 (-$300,000).
- REU supplements funding decreases to $440,000 (-$500,000).
- BCS will invest $250,000 (-$500,000) in the NSF-wide effort to increase participation of underrepresented groups in STEM fields through the NSF INCLUDES program.

Infrastructure

- FY 2018 support for infrastructure activities is continued at $700,000 (-$1.12 million). Funding partially supports BCS's contribution to 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 STATISTICS (NCSES) $48,190,000 -$2,550,000/ -5.0%

NCSES Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total	**$50.74**	**-**	**$48.19**	**-$2.55**	**-5.0%**
Infrastructure	**50.74**	**-**	**48.19**	**-2.55**	**-5.0%**

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 S&E 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* and *Women, Minorities, and Persons with Disabilities in Science and Engineering*. In addition, the data collected by NCSES serve as an important resource for researchers in SBE's Science of Science and Innovation Policy (SciSIP) program.

In FY 2018, NCSES will maintain its core programmatic data collection and publication activities while striving to preserve recent gains in data quality and coverage. To operate within estimated funding levels, NCSES will apply early results from its ongoing research in the new area of adaptive design methods that promises to reduce data collection effort while maintaining quality.

FY 2018 Summary

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

Infrastructure

In FY 2018, support for NCSES infrastructure activities total $48.19 million, a decrease of $2.55 million. Funding at this level supports NCSES's core data collection and analytic activities.

- Continued support for the National Survey of College Graduates and the Survey of Doctorate Recipients coupled with the accelerated implementation of advanced data collection techniques to operate within the FY 2018 Request funding level.

- In FY 2018, the purchase of external, open market data sets will occur at a reduced level, and current efforts to meet modern functionality and usability standards of online data systems and tools will be decreased.

SBE OFFICE OF MULTIDISCIPLINARY ACTIVITIES (SMA) $23,450,000

-$4,870,000 / -17.2%

SMA Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$28.31**	**-**	**$23.45**	**-$4.86**	**-17.2%**
Research	**18.82**	**-**	**15.75**	**-3.07**	**-16.3%**
Education	**7.13**	**-**	**5.95**	**-1.18**	**-16.6%**
Infrastructure	**2.36**	**-**	**1.75**	**-0.61**	**-25.8%**
Research Resources	2.36	-	1.75	-0.61	-25.8%

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), REU Sites, and SBE Postdoctoral Research Fellowships (SPRF). SMA will play a critical role in several crosscutting NSF investments in FY 2018: UtB; cybersecurity, via SaTC; innovation, via I-Corps™; interdisciplinary research and training, via activities such as the SBE Postdoctoral Research Fellowship-Fundamental Research (SPRF-FR) track; and the science of learning core program. 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, such as SBE's Robust and Reliable Science funding activity initiated with a Dear Colleague Letter from SMA. All areas of SBE sciences are represented in the SMA portfolio.

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

FY 2018 Summary

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

Research

- 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 $5.0 million, a decrease of $1.08 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.

Education

Support for education activities in SMA will include:

- SMA investments in the REU Sites (-$730,000, to a total of $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 fundamental research (SPRF-FR). FY 2018 Request funding for these programs is unchanged at $1.50 million for each activity.

Infrastructure

- A reduction of $610,000 in Research Resources is primarily associated with the sunsetting of SMA-supported CIF21 activities in FY 2017, partially offset with increased FY 2016 actual support for other infrastructure investments.

OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE) $44,020,000
-$5,050,000 / -10.3%

OISE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
OISE	**$49.07**	**-**	**$44.02**	**-$5.05**	**-10.3%**

About OISE

The Office of International Science and Engineering (OISE) is the NSF focal point for international science and engineering activities. OISE's mission is to promote an integrated, Foundation-wide international engagement strategy and manage internationally-focused programs that are innovative and catalytic. OISE focuses on international activities to promote innovation among the U.S. research community through access to international knowledge, infrastructure, and capabilities. OISE's FY 2018 budget focuses on three activities: (1) promoting the development of a globally competent U.S. workforce, (2) facilitating and supporting international partnerships to leverage NSF and foreign resources, and (3) providing opportunities for U.S. leadership to shape the global science and engineering agenda.

To realign the office's programs with its mission, several programs will be suspended and/or terminated. The East Asia-Pacific Summer Institute (EAPSI) program will be suspended to review the program and its outcomes. Funding used in previous years for the International Research Fellowship Program (IRFP) will be integrated into the International Research Experience for Students (IRES) program to provide global research experiences to undergraduate and graduate students. IRES will expand to include a track based on the successes of the Pan-American Advanced Studies Institutes Program for global Advanced Studies Institutes, a program that trained cohorts of scientists and engineers. Both the Catalyzing New International Collaborations (CNIC) and the Science Across Virtual Institutes (SAVI) programs were sunset in FY 2017.

Using lessons learned from SAVI, OISE will expand efforts to advance transformative science and engineering research by launching the Accelerating Research through International Networks (AccelNet) program. AccelNet will create international network-to-network partnerships, leaveraging international resources to provide new opportunities for enhanced interface between U.S. researchers and their international colleagues. AccelNet will focus on NSF priority investment areas. Each award is expected to establish a network of networks across international and interdisciplinary boundaries. AccelNet will not support core research programs of participating researchers. Instead, it will provide the funding to connect U.S. research networks with their international counterpart networks. These efforts will ensure the United States has access to the best ideas, people, and facilities wherever they may be.

OISE also manages the 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. They promote greater collaboration between U.S. and foreign counterparts and research institutions.

FY 2018 Summary

OISE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Research	$38.95	-	$32.74	-$6.21	-15.9%
Education	10.02	-	11.18	1.16	11.6%
Infrastructure	0.10	-	0.10	-	-
Total	**$49.07**	**-**	**$44.02**	**-$5.05**	**-10.3%**

Research

- In FY 2018, OISE will invest $32.74 million, $6.21 million below the FY 2016 Actual, in research programs to promote NSF's international engagement strategy. These funds will support international partnerships and networks and leverage research investments made in other parts of the Foundation.
- Research programs funded in FY 2018, including the Global Venture Fund (GVF), will support a broad range of collaborative activities (workshops, planning grants, and international research) with NSF's research and education directorates. In FY 2018, GVF will be funded at $1.00 million to support co-funding of international activities with NSF directorates and offices.
- OISE will continue support for existing awards in the Partnerships in International Research and Education (PIRE) program, which leverages NSF's resources with those of numerous foreign science and technology funding agencies. In FY 2018, PIRE will be funded at $25.06 million, or $1.62 million above the FY 2016 Actual of $23.44 million.
- With the sun-setting of SAVI, OISE will launch AccelNet, which will be funded at $1.0 million.
- The FY 2018 Request will support $900,000 for 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 this area.

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). IRES will issue a revised program solicitation in FY 2018 to include activities previously supported by Pan-American Advanced Studies Institutes (PASI) and the International Research Fellowship Program (IRFP). In FY 2018, IRES will be funded at $11.18 million, or $5.25 million above the FY 2016 Actual of $5.93 million.

Infrastructure

- In FY 2018, OISE will maintain a $100,000 investment in the National Nanotechnology Coordinated Infrastructure (NNCI) program. 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
CAREER	$0.33	-	-	-$0.33	-100.0%
Clean Energy Technology	10.45	-	-	-10.45	-100.0%
INFEWS	1.20	-	0.90	-0.30	-25.0%
Science, Engineering & Education for Sustainability	6.31	-	-	-6.31	-100.0%
Understanding the Brain	4.60	-	-	-4.60	-100.0%

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

All funding decreases/increases represent changes over the FY 2016 Actual.

- INFEWS (-$300,000 to a total of $900,000 million): OISE will co-fund meritorious proposals relevant to INFEWS with international components from across NSF. OISE will identify opportunities to catalyze new, synergistic collaborations that involve early career scientists, engineers, and students. This is an area where OISE interaction with other federal agencies (U.S. Department of State, USAID, and U.S. Department of Agriculture) is of particular benefit.

Summary and Funding Profile

In FY 2018, the number of research grant proposals is expected to increase by 27 percent compared to the FY 2016 Actual Estimate. Average annual award size and duration are expected to materially fluctuate in FY 2018 because it anticipated that the new IRES solicitation and the lauching of AccelNet will generate an increase in awards.

OISE Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	314	-	400
Number of New Awards	237	-	300
Funding Rate	75%	-	75%
Statistics for Research Grants:			
Number of Research Grant Proposals	108	-	100
Number of Research Grants	32	-	35
Funding Rate	30%	-	35%
Median Annualized Award Size	$83,369	-	$100,000
Average Annualized Award Size	$102,450	-	$250,000
Average Award Duration, in years	2.7	-	3.0

Program Monitoring and Evaluation

External Program Evaluations and Studies:
- In FY 2018, OISE will fund an evaluation of the IRES program. A request for proposals will be issued by January 2018 and the final results are expected in January 2019.

Committees of Visitors (COV):
- In FY 2018, a COV will review OISE's programs and activities.

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 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	488	-	500
Other Professionals	52	-	50
Postdoctoral Associates	182	-	200
Graduate Students	147	-	150
Undergraduate Students	97	-	100
Total Number of People	**966**	**-**	**1,000**

OFFICE OF POLAR PROGRAMS (OPP) $409,180,000

-$39,690,000 / -8.8%

OPP Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Research	**$123.31**	**-**	**$110.58**	**-$12.73**	**-10.3%**
CAREER	1.58	-	1.26	-0.32	-20.3%
Long Term Ecological Research (LTER)	2.09	-	2.25	0.16	7.7%
Education	**2.47**	**-**	**1.35**	**-1.12**	**-45.3%**
Infrastructure	**323.09**	**-**	**297.25**	**-25.84**	**-8.0%**
Arctic Research Support and Logistics	44.11	-	36.11	-8.00	-18.1%
IceCube Nutrino Observatory (IceCube)	5.23	-	3.50	-1.73	-33.1%
U.S. Antarctic Facilities and Logistics	196.53	-	177.85	-18.68	-9.5%
U.S. Antarctic Logistical Support	67.52	-	71.00	3.48	5.2%
Geodesy Advancing Geosciences and EarthScope	1.32	-	1.32	-	-
Seismological Facilities for Advancement of Geoscience & EarthScope	1.29	-	1.29	-	-
Polar Environment, Safety, and Health (PESH)	7.09	-	6.18	-0.91	-12.8%
Facilities Pre-Construction Planning	14.50	-	1.80	-12.70	-87.6%
Total	**$448.87**	**-**	**$409.18**	**-$39.69**	**-8.8%**

About OPP

The Office of Polar Programs (OPP) is the primary U.S. supporter of fundamental research in the polar regions. In addition, NSF provides interagency leadership for U.S. activities in polar regions. 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. In the Antarctic, per Presidential Memorandum 6646, NSF manages all U.S. activities as a single, integrated program, making Antarctic research possible for scientists supported by NSF and by other U.S. 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. The U.S. Antarctic Program research activity supported 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 System.

OPP supports investments in core research and education and provides research support and infrastructure, such as permanent stations and temporary field camps in the Antarctic and the Arctic. OPP's FY 2018 Budget Request is influenced by three key priorities: (1) maintaining strong disciplinary programs that provide a base for our investments in cross-disciplinary system science programs; (2) maintaining U.S. research community activities in polar system science and; (3) supporting critical facilities that enable frontier research in the Earth's polar regions. These priorities reflect opportunities for fundamental scientific discovery uniquely possible in polar regions, as well as studies to investigate the causes and future trajectory of changes now being observed at the poles that could impact global systems. This work will implement the Foundation's lead-agency role in facilitating the Nation's investment in polar science, whereby research supported by OPP will elucidate the causes and likely impacts of the interaction of polar regions with the larger planet, thus providing a basis for future policy decisions.

In addition to shared cross-directorate basic research objectives, OPP investments will be guided by recent sponsored studies to identify priority areas and ensure effective polar research programs:

- For the Arctic, the Interagency Arctic Research Policy Committee's (IARPC) *Arctic Research Plan: FY 2013-2017*,[1] the *National Ocean Policy Implementation Strategy*[2] and the World Meteorological Organization's *Year of Polar Prediction Implementation Plan*[3] inform science investment priorities. Efforts to build an integrated research capacity to address the potential opportunities and challenges of Arctic change for the nation's security and economics and well-being of Arctic residents will continue.
- For the Antarctic, the 2015 NRC report *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research*[4] inform science investment priorities. Specifically, in 2018, OPP will initiate support of a five-year deep field program to study the Thwaites Glacier Region that was the highest priority in that study. The Thwaites program will be jointly funded, including shared logistics, with the National Research Council of the UK.

All funding decreases/increases represent changes over the FY 2016 Actual.

- In FY 2018, OPP will reduce research funding by $12.73 million, to a total of $110.58 million. This will be accomplished by making fewer awards in polar science programs and by reducing OPP's support for science coordination and workshop activities.
- Support for early-career researchers remains an OPP priority. OPP will support CAREER grants at $1.26 million.
- Funding for Long Term Ecological Research (LTER) increases by $160,000, to $2.25 million, reflecting the two projects in the Antarctic and one new project in the Arctic.
- Education activities across OPP will be supported at a level of $1.35 million, which includes funds for postdoctoral fellows through NRT and continuing commitment to the Research Experiences for Undergraduates (REU) program.
- A continued investment of $500,000 will contribute polar research efforts to the cross-directorate Risk and Resilience emphasis area through the PREEVENTS program.
- OPP will phase out SEES funding as that program reaches its planned termination.

[1] www.iarpccollaborations.org/plan/index.html
[2] https://obamawhitehouse.archives.gov/sites/default/files/docs/nop_highlights__annual_report_final_-_150310.pdf
[3] www.polarprediction.net/documents/implementation-science-plans/
[4] www.nap.edu/catalog/21741/a-strategic-vision-for-nsf-investments-in-antarctic-and-southern-ocean-research

Polar Funding for Facilities

OPP Funding for Facilities
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Facilities (Total)	**$316.00**	**-**	**$291.07**	**-$24.93**	**-7.9%**
Arctic Research Support and Logistics	44.11	-	36.11	-8.00	-18.1%
Geodesy Advancing Geosciences and Earthscope (GAGE)	1.32	-	1.32	-	-
IceCube Neutrino Observatory[1]	5.23	-	3.50	-1.73	-33.1%
Seismological Facilities for Advancement of Geosciences and Earthscope (SAGE)	1.29	-	1.29	-	-
U.S. Antarctic Facilities and Logistics	196.53	-	177.85	-18.68	-9.5%
AIMS Pre-construction planning	*14.50*	-	*1.80*	*-12.70*	*-87.6%*
U.S. Antarctic Logistical Support	67.52	-	71.00	3.48	5.2%

- Arctic Research Support & Logistics (ARSL) funding provides support for Arctic researchers, including access to airplanes, helicopters, research vessels including icebreakers, and field camps for approximately 140 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. ARSL support will be reduced by $8.0 million, to $36.11 million, in concert with a reduction in Arctic science awards.
- OPPs funding for the Geodesy Advancing Geosciences and EarthScope (GAGE) and the Seismological Facilities for Advancement of Geoscience and EarthScope (SAGE) facilities will continue at the same level as FY 2016.
- IceCube Neutrino Observatory support funding will decrease $1.73 million, to $3.50 million. The funding level in FY 2016 reflected an extension of the prior cooperative agreement while a new agreement was competitively awarded. This facility is jointly funded by MPS.
- U.S. Antarctic Facilities and Logistics funding will be reduced $18.68 million, to $177.85 million, in concert with a reduction of Antarctic science awards.
- For Antarctica, a 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*.[5] NSF issued a formal response to this report in March 2013.[6] Emphases include safety and health improvements as well as planning for renewal of outdated facilities.
- In particular, investments of $1.80 million will be made to bring the Antarctic Infrastructure Modernization for Science (AIMS) project to the final design review stage and to prepare for the construction phase. The AIMS program will consolidate the footprint and core facilities at McMurdo station toward significantly enhanced efficiency and cost-effectiveness of science support.
- U.S. Antarctic Logistical Support funding increases by $3.48, million to $71.0 million, to enhance support of critical Antarctic airlift and the marine based annual resupply mission.

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

Funding Profile

OPP's research portfolio entails a broad array of scientific fields including aeronomy and astrophysics, terrestrial and marine biology, geology and geophysics, atmospheric and oceanic science, glaciology and Arctic social science. In addition, OPP-managed logistics and infrastructure facilitates complementary polar research conducted by other federal agencies.

In FY 2018, the number of research grant proposals submitted is expected to remain steady and OPP expects to award about 200 research grants. The average annual award amount is anticipated to increase slightly in FY 2018 relative to the FY 2016 Actual.

OPP Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Statistics for Competitive Awards:			
Number of Proposals	959	-	950
Number of New Awards	282	-	200
Funding Rate	29%	-	22%
Statistics for Research Grants:			
Number of Research Grant Proposals	929	-	900
Number of Research Grants	257	-	200
Funding Rate	28%	-	22%
Median Annualized Award Size	$156,305	-	$160,100
Average Annualized Award Size	$198,243	-	$200,900
Average Award Duration, in years	2.6	-	2.6

Program Monitoring and Evaluation

Workshops and Reports:
OPP sponsored several studies over the past six years to gather direction from the polar science community and to help plan for effective research programs into the future. The findings and recommendations from these reports continue to influence and drive OPP funding and investment policy decisions as described above. In addition, the execution of the merit review process by OPP has been recently reviewed via the GEO Advisory Committee.

Committees of Visitors (COV):

- In FY 2016, separate COVs were conducted to review the Antarctic Sciences Section (ANT) and the Arctic Sciences Section (ARC). The COV report for each section was presented to the GEO Advisory Committee, which convened in October of 2016. The COVs found that the programs under review were well managed by each section and provided several useful recommendations.
- The next COVs for ANT and ARC will be conducted in FY 2020.

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 OPP Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	1,083	-	1,000
Other Professionals	569	-	400
Postdoctoral Associates	113	-	90
Graduate Students	382	-	400
Undergraduate Students	344	-	200
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	2,491	-	2,090

INTEGRATIVE ACTIVITIES (IA) $315,740,000
-$110,820,000 / -26.0%

IA Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
EAC	-	-	$3.00	$3.00	N/A
EPSCoR	160.03	-	100.00	-60.03	-37.5%
Graduate Research Fellowship Program	165.96	-	123.27	-42.69	-25.7%
INSPIRE	4.25	-	-	-4.25	-100.0%
Major Research Instrumentation	79.55	-	75.00	-4.55	-5.7%
NSF INCLUDES	1.90	-	2.00	0.10	5.0%
Planning and Policy Support	-	-	4.43	4.43	N/A
Research Investment Communications	3.14	-	3.14	-	-
Science and Technology Centers Class of 2016	5.00	-	-	-5.00	-100.0%
Science and Technology Centers Administration	0.99	-	0.90	-0.09	-9.4%
Science and Technology Policy Institute	4.74	-	4.00	-0.74	-15.6%
STAR METRICS	1.00	-	-	-1.00	-100.0%
Total	**$426.56**	**-**	**$315.74**	**-$110.82**	**-26.0%**

The FY 2018 Budget Request for Integrative Activities (IA) is $315.74 million. This request highlights NSF's continuing emphasis on building capacity across the research and education enterprise, including investments in the Established Program to Stimulate Competitive Research (EPSCoR). These investments are intended to improve the research competitiveness of U.S. states and territories ("jurisdictions") by investing in their academic infrastructure in areas of science and engineering that are supported by NSF and are also critical to that jurisdiction's long-range science and technology strategy. The Major Research Instrumentation Program (MRI) provides organizations with opportunities to acquire and/or develop shared state-of-the-art instrumentation that supports their research and research training goals. Investments in human infrastructure, through programs such as the Graduate Research Fellowship Program (GRFP) and NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES), continue to be a major emphasis for NSF.

In FY 2018, there will be an agency-wide effort to encourage and support Convergence; this effort will focus on building a consensus on the definition of "convergence," generating calls for proposals that integrate convergence with other NSF Big Ideas, and identifying best mechanisms for reviewing convergent proposals. In addition, NSF will start to ramp up the NSF 2026 program, named in celebration of the Nation's Sestercentennial. NSF 2026 is an NSF Big Idea dedicated to supporting bold, long-term foundational research questions that will lead to major breakthroughs in science and engineering.

About IA

IA expands the National Science Foundation's capacity for research and innovation through ideation, experimentation, and assessment. IA has five main goals:

- To strengthen alignment of NSF's activities with its mission;
- To enhance NSF's ability to solicit, review, award, and manage an evolving portfolio;
- To develop high-performance analytics and tools that will reveal new insights into the award portfolio and NSF's policies and practices;

- To advance research infrastructure that will enable pioneering research across the United States;
- To promulgate an inclusive national education and research enterprise that supports the development of outstanding researchers.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

- Evaluation and Assessment Capability (EAC) funding in FY 2018 is $3.0 million. It will focus on co-funding contracts for program evaluations, improvements in data quality, NSF-wide access to data analytics tools, and activities focused on informing organizational learning and improvement in the performance of NSF programs and day-to-day operations.

- EPSCoR (-$60.03 million, to a total of $100.0 million) funding in FY 2018 will focus on Research Infrastructure Improvement Track-1 awards, investments in NSF-supported areas of science and engineering that are aligned with science and technology priority areas as identified by the jurisdictions.

- GRFP invests (-$42.69 million, to a total of $123.27 million) in the U.S. in science, technology, engineering, and mathematics (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). The program will support 1,000 new fellowships with a cost of education allowance of $12,000 and a stipend of $34,000. IA provides 50 percent of NSF's funding for GRFP, with the remainder provided by the Directorate for Education and Human Resources (EHR). For additional information on GRFP, see the discussion on Major Investments in STEM Graduate Education narrative in the NSF-Wide Investments chapter.

- In FY 2017, the Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) pilot ended and a new funding mechanism encompassing elements of INSPIRE was developed; Research Advanced by Interdisciplinary Research and Engineering (RAISE). The RAISE mechanism supports bold, potentially transformative interdisciplinary research that transcends programmatic scope. RAISE guidelines are published in the 2017 NSF Proposal and Award Policy Procedures Guide and the funding mechanism is available to any researcher conducting transformational, interdisciplinary research in fields that NSF supports. Remaining FY 2016 INSPIRE funding will allow co-funding for about 5 RAISE awards at up-to-$1.0-million each in FY 2017. Starting in FY 2018, IA co-funding will be eliminated and each directorate will support bold, potentially transformative interdisciplinary research through the RAISE mechanism, coordinating with other directorates and divisions, as necessary.

- The MRI program (-$4.55 million, to a total of $75.0 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 goal of NSF INCLUDES (+$0.10 million, to a total of $2.0 million) is to develop a talented, innovative, and capable science and engineering workforce that reflects the diversity of our society. If the United States is to remain the world leader with respect to innovations and discoveries in STEM, it must identify and develop talent from all sectors of society to become tomorrow's STEM professionals. Providing opportunities and support for members of all communities and sectors across the Nation is both necessary for the Nation's economic welfare and as part of NSF's commitment to equity. NSF INCLUDES, which began in FY 2015, will be in existence through FY 2025.

- Planning and Policy Support funding in FY 2018 is $4.43 million. This program supports select NSF-wide policy and planning activities, including support for workshops, conferences, and other long-term planning activities for NSF's Big Ideas. It also aggregates a number of similar activities previously supported elsewhere, 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 STEM students from underrepresented groups. The FY 2018 Budget Request will also fund NSF collaborations with the National Academies, including the Government-University-Industry Research Roundtable (GUIRR),[1] and the Committee on Science, Engineering, Medicine, and Public Policy (CoSEMPuP).[2]

- Research Investment Communications (RIC) funding in FY 2018 is $3.14 million, equal to the FY 2016 Actual. 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 2018, 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) program (-$5.09 million, to a total of $900,000) 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 reduction in budget reflects the transfer of funding for the newest cohort of four STC awards from IA to the relevant managing directorates. The FY 2018 Request will provide support for post award management for the 12 existing centers.

- The Science and Technology Policy Institute (STPI) (-$740,000, to a total of $4.0 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).

- Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness, and Science (STAR METRICS) (-$1.0 million, to a total of $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 is being eliminated as this pilot activity has served its purpose.

[1] http://sites.nationalacademies.org/pga/guirr/index.htm
[2] http://sites.nationalacademies.org/pga/cosepup/index.htm

Program Monitoring and Evaluation

EAC was established to provide NSF with enhanced capability to operate from a basis of evidence in program and policy decisions; to more consistently assess the influence of its investments; and to establish a culture of evidence-based planning and policy making. EAC has been responsible for establishing mechanisms for NSF-wide leadership and coordination in program and portfolio evaluation, providing expert support and resources for data collection, integration, and management, and improving NSF-wide evaluation capacity.

In FY 2017, EAC staff is evaluating five activities and has negotiated nine evaluation/monitoring contracts in collaboration with lead-directorates of the programs. Each of these projects is summarized below.

Internal Program Evaluations and Studies:

- Broader Impacts (BI). This study focuses on the nature of BI evidence in proposals, review panel summaries, and annual reports. Findings from this ongoing project will inform guidance on how principal investigators, reviewers, and COV members consider broader impacts of the research.
- Intergovernmental Personnel Act (IPA). The purpose of this project is to assess the effect of the policy change requiring a mandatory 10 percent cost share on NSF's IPA program. Comprehensive results from the pilot, expected before the end of FY 2018, will inform NSF about the effects of that policy.
- Innovations at the Nexus of Food, Water and Energy Systems (INFEWS). The purpose of this study is to determine to what extent and how the scientific community has addressed all of the systems in their responses to the FY 2015 and FY 2016 NSF INFEWS solicitations. This will also address what changes this examination of the portfolio suggests for the next solicitation. Final results are anticipated before the end of FY 2017.
- National Academies (NA). The purpose of this project is to assess the impact of NSF-funded workshops and conferences convened by NA. Using data provided by NA and information gleaned from public websites, EAC is compiling information on number of report downloads, mention of NA studies in publications and legislation, and influence of such studies on NSF program solicitations. This work is ongoing and will be continually updated as NSF funds new awards to NA.
- Patents. This study examines patent data from the US Patent and Trademark Office (USPTO) for links to NSF awards. The results, such as time between the award of the grant and the subsequent patent, provide insights into the potential economic impacts of NSF investments.

External Program Evaluations and Studies:

- Broadening Participation (BP). This study examines how BP investments are informing research, through empirical investigations of broadening participation issues or through broadening participation implementation research on what is making a difference. Final results are anticipated before the end of FY 2018.
- Data Asset Inventory. This study will develop an inventory and assessment of the data assets currently available to support inquiry of NSF investments in human capital, particularly graduate education (excluding GRFP) and workforce development. The overarching purpose is to determine if data elements can be added to ongoing collections or standardized across collections to reduce the burden of future monitoring and evaluation efforts. Final results are anticipated before the end of FY 2017.
- GRFP. This activity encompasses the development of a data collection system that can be used to describe the fellows' graduate school experiences and track career outcomes. This system, with a potential expansion to describe the education and career trajectories of all graduate students funded by NSF, is expected to be in place before the end of FY 2020.
- NSF Innovation Corps (I-Corps™) Teams Program. This longitudinal evaluation of the I-Corps™ Teams Program assesses the impact of the program on the team members as well as their academic

institutions. The results will shed light on how I-Corps™ extends the focus of the researchers beyond the research environment. Final results are anticipated before the end of FY 2018.

- Technical assistance for NSF INCLUDES. The purpose of this project is to offer evaluation-related technical assistance to support the initial development of design, implementation, and assessment support activities for the NSF INCLUDES Launch Pilots. Technical assistance services may consist of, but are not limited to, coaching and training, experienced consultation/facilitation, tools and resources, technology, and peer learning. This technical assistance will be provided until the end of FY 2019.
- Evaluation of NSF INCLUDES. This comprehensive, developmental program-level evaluation provides formative feedback to support continuous learning and improvement during the inaugural phase of the NSF INCLUDES initiative. It will assess the processes and progress for all Launch Pilot, Alliance, and Backbone efforts for the next few years. Final results are anticipated before the end of FY 2019.
- Research Experience for Undergraduates (REU). The primary purpose of this effort is to design, build, pilot, test, and present findings for a web-based longitudinal data collection system for tracking REU Site participants. Building an evaluation framework around this data collection effort will also facilitate the measurement of participant outcomes. Final results and a proposed evaluation framework are anticipated before the end of FY 2019.
- Secure and Trustworthy Cyberspace (SaTC). This study builds on STPI findings from a review of historical data from investments in cybersecurity from 2008 to 2011. The primary emphasis of the evaluation will be on data from the inception of SaTC in 2012 to the present. An understanding of how and in what ways SaTC makes collective progress toward its goals and objectives will inform the use of these findings to refine existing and future SaTC program level activities. Final results are anticipated before the end of FY 2019.
- Science, Engineering and Education for Sustainability (SEES). This evaluation of the SEES portfolio seeks to measure the success in terms of (1) the development of new knowledge and concepts that advance the overarching goal of a sustainable human future; (2) new and productive connections made among researchers in a range of disciplines; and (3) the development of a workforce capable of meeting sustainability challenges. Final results are anticipated before the end of FY 2018.

In FY 2017, EAC will initiate three new evaluation contracts, each of which is summarized below.

- Centers for Chemical Innovation (CCI). The purpose of this comprehensive assessment is to evaluate the effectiveness of the CCI program in achieving its stated goals. Key concepts of interest are influence of CCIs on the culture of and the nature of collaborative practices in the chemical sciences. The results of this study will be used to communicate the impact of the program and to strengthen the design and operation of the program. Final results are anticipated before the end of FY 2019.
- Established Program to Stimulate Competitive Research. The purpose of this evaluation is two-fold: (1) to develop a flexible framework to explore, define, and measure research competitiveness in relation to the unique jurisdictional contexts of each EPSCoR awardee; and (2) to collect and use evidence of jurisdictional progress toward research competitiveness over time for strategic program improvement. An understanding of how and in what ways progress is made towards increased research competitiveness will inform the use of these findings to refine existing and tailor future EPSCoR program level activities. Final results are anticipated before the end of FY 2020.
- Geoscience Education (GeoEd). This evaluation will inform strategic direction by describing the extent to which the GeoEd portfolio is contributing to and progressing toward the achievement of program goals. The purpose of this evaluation is three-fold, to: (1) develop a flexible framework to define, measure, and explore value and impact; (2) provide evidence of the range, synergies, and variability across factors contributing to impact over time; and (3) strengthen the practice of evaluative inquiry for program improvement among GeoEd decision makers and stakeholders. Final results are anticipated before the end of FY 2018.

Committee of Visitors (COV):

- In 2016, a COV reviewed the Major Research Instrumentation (MRI) program and generated a largely positive report, including 10 findings and 11 recommendations. Recommendations included strategies NSF might consider to increase gender diversity in the application pool, increased support for graduate students and novel mechanisms for development of very early stage instrumentation. NSF is preparing a response to the recommendations and will publish annual updates on the COV website. The next MRI COV is anticipated in 2021.
- In 2019, a COV will review the EPSCoR Program.
- In 2020, a COV will review the Science and Technology: Integrative Activities Program.

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.

ESTABLISHED PROGRAM TO STIMULATE COMPETITIVE RESEARCH — $100,000,000 / -$60.03 / -37.5%

EPSCoR Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total	**$160.03**	**-**	**$100.00**	**-$60.03**	**-37.5%**
Research Infrastructure Improvement (RII)	131.00	-	95.00	-36.00	-27.5%
Co-Funding	27.90	-	4.00	-23.90	-85.7%
Outreach and Workshops	1.13	-	1.00	-0.13	-11.7%

EPSCoR funding in FY 2018 is $100.0 million. EPSCoR assists NSF in its statutory function "to strengthen research and education is 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.

EPSCoR uses three strategic investment tools: Research Infrastructure Improvement (RII) awards, Co-Funding, and Outreach/Workshops.

FY 2018 EPSCoR Summary

In general, approximately 15 percent of the Section's portfolio is available for new research grants and 85 percent is available for continuing grants.

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

Research Infrastructure Improvement (RII)

- RII (-$36.0 million, to a total of $95.0 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 initiatives. 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.

Co-Funding

- Co-Funding (-$23.90 million, to a total of $4.0 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.

Outreach and Workshops

- The Outreach and Workshops (-$130,000 to a total of $1.0 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, 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 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	644	-	400
Other Professionals	187	-	200
Postdoctoral Associates	96	-	40
Graduate Students	578	-	500
Undergraduate Students	624	-	300
K-12 Teachers	7,923	-	3,200
K-12 Students	92,910	-	58,700
Total Number of People	**102,962**	**-**	**63,340**

UNITED STATES ARCTIC RESEARCH COMMISSION (USARC) $1,430,000 +$0 / 0.0%

USARC Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
USARC	**$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 Enacted level. The FY 2018 Request will support three FTE funded at USARC. In addition, the FY 2018 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.

DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES (EHR) $760,550,000 -$123,550,000 / -14.0%

EHR Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	$224.32	-	$199.57	-$24.75	-11.0%
Division of Graduate Education (DGE)	278.19	-	221.29	-56.90	-20.5%
Division of Human Resource Development (HRD)	149.31	-	135.30	-14.01	-9.4%
Division of Undergraduate Education (DUE)	232.29	-	204.39	-27.90	-12.0%
Total, EHR	**$884.10**	-	**$760.55**	**-$123.55**	**-14.0%**

About EHR

The mission of the Directorate for Education and Human Resources (EHR) is to provide the research foundation to develop a diverse, science, technology, engineering, and mathematics (STEM)-literate public and workforce that is ready to advance the frontiers of science and engineering for society. This research foundation has guided and shaped EHR's portfolio and priorities for more than 60 years. While the EHR mission remains constant, the context changes in which this mission is enacted. 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.

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,~~*$760,550,000,* to remain available until September 30, ~~2017.~~*2019.*

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing

Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Education and Human Resources
FY 2018 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 2016 Appropriation	$880.00	$2.63	-$5.37	$7.87	-$1.03	$884.10
FY 2017 Annualized CR	878.33	5.37				883.70
FY 2018 Total Request	760.55					760.55
$ Change from FY 2017 Annualized CR						-$123.15
% Change from FY 2017 Annualized CR						-13.9%

Explanation of Carryover

Within the **Education and Human Resources (EHR)** account, $5.37 million was carried over into FY 2017.

Excellence Awards in Science and Engineering (EASE)
- Amount: $2.93 million
- Reason: Delays in the selection of a contractor to assist with the administration of the Presidential Awards for Excellence in Mathematics and Science Teaching program, which is managed by EHR on behalf of OSTP.
- Obligated: FY 2017 Quarter 2

Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES)
- Amount: $720,192
- Reason: Delays in obligation is due to the pre-award process for multiple new awardees.
- Obligated: FY 2017 Quarter 1

Robert Noyce Scholarship Program
- Amount: 1.62 million
- Reason: Robert Noyce program funding was carried over into FY 2017 for awards that were not ready for obligation.
- Anticipated Obligation: FY 2017 Quarter 4

The remaining $97,719 are residual funds from various EHR program activities.

2018 EHR Summary

EHR's investment in FY 2018 employs three themes, or core research areas, 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 three themes guide the design of solicitations and program activities; EHR's investments are also coordinated within these themes.[1]

As part of **broadening participation and institutional capacity**, EHR will serve as a central resource for the following:

- Co-leading, with the Directorate for Engineering (ENG), the Directorate for Geosciences (GEO), 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 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 through the Tribal Colleges and Universities Program (TCUP).
- 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 the following:

- 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 following:

- 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'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 discussed above that guide EHR's work. Findings are accumulating to inform investment, policy, and

[1] NSF Federal Advisory Committee for Education and Human Resources. (2014). *Strategic re-envisioning for the Education and Human Resources Directorate.* Arlington, VA: National Science Foundation. Retrieved from www.nsf.gov/ehr/Pubs/AC_ReEnvisioning_Report_Sept_2014_01.pdf

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 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 there is evidence that 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, through EHR, within the federal government 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. The EHR research portfolio also supports a 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 2018. 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.

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[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.
[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).

EHR's FY 2018 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 commitment to 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 partnerships.

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). In particular, EHR will provide staff support for the STEM Education Advisory Panel created by The American Innovation and Competitiveness Act (P.L. 114-329).

Major Investments

EHR Major Investments

(Dollars in Millions)

Area of Investment	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
GRFP	$166.38	-	$123.27	-$43.11	-25.9%
NSF INCLUDES	2.28	-	3.00	0.72	31.9%
INFEWS	8.81	-	4.00	-4.81	-54.6%
Improving Undergraduate STEM Education (IUSE)	87.00	-	87.00	-	-
Traineeship (NRT)[1]	31.02	-	33.05	2.03	6.5%
SaTC	49.98	-	40.00	-9.98	-20.0%
Understanding the Brain	11.00	-	9.00	-2.00	-18.2%
BRAIN Initiative	2.00	-	2.00	-	-

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 were $10,000 in FY 2016. There is no IGERT funding beyond FY 2016.

All funding decreases/increases represent changes over the FY 2016 Actual.

- Graduate Research Fellowship Program (GRFP) (-$43.11 million to a total of $123.27 million): An equal investment is provided through the Integrative Activities budget for a total GRFP investment of $246.54 million. For more information, see the Major Investments in STEM Graduate Education narrative within the NSF-Wide Investments chapter.

- NSF INCLUDES (+$720,000 to a total of $3.0 million): The Division of Human Resource Management (HRD) 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) (-$4.81 million to a total of $3.0 million): This investment 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) ($87.0 million, equal to FY 2016 Actual): EHR will lead the NSF-wide IUSE activity. For more information, see the IUSE narrative within the NSF-Wide Investments chapter. In FY 2018, $15.0 million is included for IUSE: Hispanic Serving Institutions (IUSE: HSI), with funding provided through the Division of Undergraduate Education (DUE) and HRD. The primary goals of the IUSE: HSI activity are to promote research on engaged student learning at HSIs, to incentivize institutional and community transformation, and to promote fundamental research about what it takes to diversify and increase participation in STEM effectively, including research that improves our understanding of how to build institutional capacity at HSIs. These activities will address the Nation's need to make the STEM workforce more inclusive.

- NSF Research Traineeship (NRT) (+$2.02 million to a total of $33.05 million): The investment for FY 2018 NRT activities is $33.05 million, of which $4.0 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) (-$9.98 million to a total of $40.0 million): Through the CyberCorps®: Scholarship for Service (SfS) program, EHR will support SaTC activities.

- Understanding the Brain (UtB) (-$2.0 million to a total of $9.0 million): In FY 2018, through the NRT, EHR core research (ECR), IUSE, and Discovery Research PreK-12 (DRK-12) programs, EHR will invest in cognitive and learning sciences research efforts 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. This investment includes $2.0 million for the brain research through the 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 2018, the number of research grant proposals is estimated at 3,300. EHR expects to award approximately 475 research grants with an average annualized award size and duration of $332,900 and 2.9 years, respectively.

EHR Funding Profile

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Request
Statistics for Competitive Awards:			
Number of Proposals	4,416	-	4,500
Number of New Awards	908	-	810
Funding Rate	21%	-	18%
Statistics for Research Grants:			
Number of Research Grant Proposals	3,267	-	3,300
Number of Research Grants	531	-	475
Funding Rate	16%	-	14%
Median Annualized Award Size	$199,801	-	$199,800
Average Annualized Award Size	$332,900	-	$332,900
Average Award Duration, in years	2.9	-	2.9

Program Monitoring and Evaluation

Workshops and Reports:

- 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. 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 late 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.

Committees of Visitors (COV):

- In October 2016, a COV was held for the EHR Core Research (ECR) program, which spans all four divisions in the directorate, and another COV reviewed the following programs managed by DUE: Transforming Undergraduate Education in STEM (DUE: TUES), STEM Talent Expansion Program (STEP), Widening Implementation and Demonstration of Evidence-Based Reforms (WIDER), and Improving Undergraduate STEM Education (IUSE: EHR).
- In November 2016, a division-wide COV reviewed all programs managed by HRD: Advancement of Women in Academic Science and Engineering Careers (HRD: ADVANCE), Alliances for Graduate Education and the Professoriate (AGEP), Centers for Research Excellence in Science and Technology (CREST), Historically Black Colleges and Universities–Undergraduate Program (HBCU-UP), Louis Stokes Alliances for Minority Participation (LSAMP), and TCUP.
- An evaluation of the Robert Noyce Teacher Scholarship Program, conducted by Abt Associates, was completed in FY 2017.
- The Division of Graduate Education (DGE) plans to hold a division-wide COV in FY 2018 to review SfS, NRT, and GRFP.

- DUE plans to hold a division-wide COV in FY 2018 to review the Advanced Technological Education (ATE) program, IUSE: EHR, the NSF Scholarships in STEM (S-STEM) program, and Noyce.

Evaluation activities tentatively scheduled for FY 2017 and FY 2018:
- ADVANCE plans to initiate a program evaluation.
- IUSE plans to initiate an evaluation.
- The Graduate Research Internship Program (GRIP) plans to initiate a program evaluation.

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.

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 EHR Activities

	FY 2016 Actual Estimate	FY 2017 (TBD)	FY 2018 Estimate
Senior Researchers	6,400	-	5,500
Other Professionals	2,300	-	2,000
Postdoctoral Associates	300	-	300
Graduate Students	10,851	-	9,400
Undergraduate Students	16,000	-	13,800
K-12 Teachers	36,200	-	31,300
K-12 Students	81,900	-	70,800
Total Number of People	153,951	-	133,100

DIVISION OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS (DRL) $199,570,000 -$24,750,000 / -11.0%

DRL Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, DRL	**$224.32**	**-**	**$199.57**	**-$24.75**	**-11.0%**
Learning and Learning Environments	**25.65**	**-**	**34.33**	**$8.68**	**33.9%**
EHR Core Research (ECR): STEM Learning	25.65	-	34.33	8.68	33.9%
Broadening Participation and Institutional Capacity	**146.80**	**-**	**145.24**	**-$1.56**	-1.1%
Advancing Informal STEM Learning (AISL)	62.50	-	62.50	-	-
Discovery Research PreK-12 (DRK-12)	84.30	-	82.74	-1.56	-1.8%
STEM Professional Workforce	**51.87**	**-**	**20.00**	**-$31.87**	-61.4%
Science, Technology, Engineering, Mathematics + Computing (STEM + C) Partnerships	51.87	-	20.00	-31.87	-61.4%

The Division of Research on Learning in Formal and Informal Settings (DRL) invests in foundational research to advance understanding about STEM learning and teaching. Advances in STEM learning ultimately support individuals who pursue STEM careers, as well as the Nation's STEM workforce more broadly. 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 FY 2018 Budget Request for DRL is $199.57 million which will allow DRL to:

- Invest across its programs in research and development at the early childhood level to foster STEM learning.
- Invest in research and development supporting computer science education, including research on computational thinking and the integration of computing with other STEM disciplines.
- 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.
- Provide a focus on research and development on STEM learning cutting across formal and informal settings.
- Fund research and development related to understanding, measuring, and enhancing socioemotional skills, such as persistence, teamwork, and learning to learn.

In FY 2018, through the STEM + C Partnerships (STEM + C) program, DRL will lead EHR's involvement with the CISE directorate in Computer Science for All: Researcher Practitioner Partnerships (CSforAll: RPP), by making $10.0 million available to advance the effective teaching and learning of computer science in K-12 education. An equal investment is provided through CISE's budget for a total CSforAll: RPP investment of $20.0 million. DRL will also contribute $5.0 million to NSF's UtB initiative; this includes $2.0 million for the Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative to support research on the neural and cognitive basis of STEM learning.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Learning and Learning Environments

- ECR: STEM Learning (+$8.68 million to a total of $34.33 million): This program will continue to 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 FY 2018 will be early childhood STEM learning, which will be highlighted in ECR along with an emphasis on advanced methodologies to support foundational research on STEM learning. ECR funding will enable strategic and coordinated research investments 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 support data science-enabled research on STEM learning, and foundational research in relation to cyberlearning (including technology-based learning in the workplace) along with computational thinking.

Broadening Participation and Institutional Capacity in STEM

- Broadening participation investments in FY 2018 will continue to focus on understanding changing demographics and building talent so that diversity is an asset for science. DRL's funding for AISL is $62.50 million (level with FY 2016 Actual). 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, cyberlearning, and coding. 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 to support collaborative partnerships across institutions that support informal science learning.
- FY 2018 DRK-12 investments total $82.74 million (-$1.56 million). These funds are aimed at improving STEM achievement for all preK-12 students, including innovative areas such as computer science and engineering. Investments will focus on enabling success for preK-12 students in all groups and across diverse educational settings including technology-supported learning environments. Of particular interest is enhancing disciplinary-specific and interdisciplinary teaching and learning in all STEM disciplines via evidence-based instructional resources and tools. Teacher development and education initiatives focus on preparing the Nation's diverse learners for future needs in STEM innovation. DRK-12 is also focused on design and implementation research on policy and practice issues that support STEM learning and learning environments for 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 (-$31.87 million to $20.0 million). Of this budget, $10.0 million will be used to support CSforAll: RPP, in collaboration with CISE. The remaining budget will be targeted at continuing obligations within STEM + C as well as collaborative funding with other DRL programs on the topic of integrating computing with other STEM disciplines. In FY 2018, STEM + C will not run a new competition, but the program will use the year to evaluate its portfolio as well as relations to other EHR programs, to inform plans for FY 2019.

DIVISION OF GRADUATE EDUCATION (DGE) $221,290,000
-$56,900,000 / -20.5%

DGE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, DGE	**$278.19**	**-**	**$221.29**	**-$56.90**	**-20.5%**
Learning and Learning Environments	**14.57**	**-**	**9.00**	**-5.57**	**-38.2%**
Project and Program Evaluation (PPE)	14.57	-	9.00	-5.57	-38.2%
STEM Professional Workforce	**263.40**	**-**	**212.29**	**-51.11**	**-19.4%**
EHR Core Research (ECR): STEM Professional	16.00	-	15.97	-0.03	-0.2%
CyberCorps®: Scholarship for Service (SfS)	49.98	-	40.00	-9.98	-20.0%
Graduate Research Fellowship Program (GRFP)	166.38	-	123.27	-43.11	-25.9%
NSF Research Traineeship (NRT)[1]	31.03	-	33.05	2.02	6.5%

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and were $10,000 in FY 2016. There is no IGERT funding beyond FY 2016.

The Division of Graduate Education (DGE) provides leaders across NSF for investments that support U.S. graduate students in STEM, and for improvement and innovation in graduate education to prepare tomorrow's STEM leaders. DGE focuses on the development of the broad STEM professional workforce through graduate education.

The FY 2018 Budget Request for DGE is $221.29 million. This budget will allow DGE to emphasize research on the development of the STEM workforce through ECR. SfS will continue its collaborations with other federal agencies to explore mechanisms through which members of this cybersecurity workforce can continue to contribute to the government throughout their careers. In addition, DGE will continue activities in the SfS program that strengthen and expand the capacity of universities to develop a diverse cadre of cybersecurity experts for the nation. The SfS program will also support research and development in program, curriculum, and assessment related to cybersecurity education needs across all levels of higher education. Finally, DGE will continue its efforts to engage community colleges in the preparation of cybersecurity professionals.

In FY 2018 DGE will continue to promote interdisciplinary research traineeships for graduate students in high priority areas of STEM through the NRT program. DGE will also continue to promote innovation in graduate education through the Innovations in Graduate Education (IGE) track of the NRT program, along with new research and professional development opportunities for graduate students supported through other NSF mechanisms. DGE will sustain its emphasis on broadening participation in the STEM workforce through outreach to Hispanic-serving institutions, historically black colleges and universities, and tribal colleges and universities.

DGE will support Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) at a level of $3.0 million through the NRT program. With the Directorate for Biological Sciences, DGE has administrative and intellectual responsibility for the implementation of the *NSF Strategic Framework for Investments in Graduate Education: FY 2016-FY 2020*.[8] DGE also leads the EHR evaluation portfolio (particularly in the area of human capital), and is co-lead with the National Institutes of Health in the FC-STEM IWG on Graduate Education.

[8] National Science Foundation. (2016). *The National Science Foundation strategic framework for investments in graduate education: FY 2016-FY 2020.* Arlington, VA: NSF. Retrieved from www.nsf.gov/pubs/2016/nsf16074/nsf16074.pdf

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Learning and Learning Environments

- 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. PPE efforts (-$5.57 million to a total of $9.0 million) 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).

STEM Professional Workforce

- ECR: STEM Professional Workforce Preparation investments will expand the knowledge base to improve STEM professional workforce development at all educational levels through development of models, research, and evaluation, and they will allow translation of the results of the research for adoption/adaptation in workforce and education programs. DGE's FY 2018 funding for its ECR program is $15.97 million (-$30,000).
- SfS (-$9.98 million to a total of $40.0 million): 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 this funding will allow institutions 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 (-$43.11 million to a total of $123.27 million): The program will support 1,000 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.
- EHR's NRT investment (+$2.02 to a total of $33.05 million) will continue to support projects in the NSF-wide priorities INFEWS and UtB. Of the NRT budget, $4.0 million is dedicated to supporting the IGE track. Through IGE, NRT will challenge the field to devise, implement, and assess cutting-edge innovations in preparing graduate students to be researchers in the evolving areas supported by INFEWS and UtB and 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) $135,300,000
-$14,010,000 / -9.4%

HRD Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Total, HRD	**$149.31**	**-**	**$135.30**	**-$14.01**	**-9.4%**
Learning and Learning Environments	**58.49**	**-**	**56.53**	**-1.96**	**-3.4%**
ADVANCE	1.48	-	1.53	0.05	3.4%
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.00	-1.00	-12.5%
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	35.01	-	35.00	-0.01	-0.0%
Tribal Colleges and Universities Program (TCUP)	14.01	-	13.00	-1.01	-7.2%
Broadening Participation & Institutional Capacity	**61.19**	**-**	**50.95**	**-10.24**	-16.7%
EHR Core Research (ECR): Broadening Participation and Institutional Capacity in STEM	12.90	-	7.28	-5.62	-43.6%
NSF INCLUDES	2.28	-	3.00	0.72	31.9%
Louis Stokes Alliances for Minority Participation (LSAMP)	46.01	-	40.67	-5.34	-11.6%
STEM Professional Workforce	**29.63**	**-**	**27.82**	**-1.81**	-6.1%
Centers for Research Excellence in Science and Technology (CREST)	24.04	-	24.00	-0.04	-0.2%
Excellence Awards in Science and Engineering (EASE)	5.59	-	3.82	-1.77	-31.7%

The Division of Human Resource Development (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.

The FY 2018 Budget Request for HRD is $135.30 million. EHR will continue its 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. As NSF INCLUDES enters its third year, HRD programs will continue to build strong linkages with it to create seamless connections with the existing broadening participation portfolio.

The HBCU-UP program will collaborate with the R&RA directorates to encourage HBCU faculty to submit proposals to other directorates and enhance research capacity at HBCUs. The CREST program will encourage institutional collaborations with other federal agencies, state governments, national laboratories, private sector research laboratories, and K-12 entities to advance knowledge and education on research that is of significance to the Nation.

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.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Learning and Learning Environments

- In FY 2018, the ADVANCE program's cumulative budget, consisting of EHR funds and other directorate contributions, reduced 67 percent (or -$9.96 million) to $4.90 million. HRD's funding for ADVANCE is $1.53 million (+$50,000).
- AGEP (-$1.0 million to a total of $7.0 million): AGEP will support innovative and sustainable ways to promote inclusion in the STEM academic workforce, and will continue to implement new strategies to work with the NRT program and GRFP focusing on transitions from graduate to postdoctoral training to increase STEM career opportunities.
- HRD's funding for HBCU-UP is $35.0 million (-$10,000). This funding will invest in broadening participation research centers, which will enable the HBCU community to develop a long-term plan for the integration of research and education in the science of broadening participation, and foster knowledge transfer about research and education advances.
- TCUP will support the design, implementation, and assessment of comprehensive institutional improvements in STEM instruction and research capacity (-$1.01 million to a total of $13.0 million).

Broadening Participation and Institutional Capacity in STEM

- In FY 2018, HRD will continue to provide strategic direction and guidance for the broadening participation and institutional capacity component of ECR (-$5.62 million to a total of $7.28 million). Minority serving institutions 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. In FY 2018, ECR funding will also support the IUSE: HSI activity.
- HRD's funding for NSF INCLUDES will support the development of the NSF INCLUDES Alliances, the Backbone Organization, and additional Design and Development Launch Pilots (+$720,000 to a total of $3.0 million). HRD will play a key role in the development of metrics and approaches for the assessment of NSF INCLUDES and other investments in broadening participation.
- LSAMP (-$5.34 million to a total of $40.67 million). This funding will support an increased focus on STEM research and evaluation to expand knowledge about effective strategies for student recruitment, retention, and persistence in STEM programs. Decreased support to LSAMP will reduce funding for Pre-Alliance Planning grants and Bridge to the Baccalaureate Alliances.

STEM Professional Workforce

- CREST will continue to grow the new Postdoctoral Research Fellowship track introduced in FY 2016 which fosters increased collaborations across the centers and builds research capacity at minority serving institutions. HRD's funding for CREST is $24.0 million (-$40,000).
- EASE (-$1.77 million to a total of $3.82 million): Collaborative efforts among the EASE, Noyce, and DRK-12 programs support the professional development of preK-12 teachers, by piloting models for teacher leadership.

DIVISION OF UNDERGRADUATE EDUCATION (DUE) $204,390,000
-$27,900,000 / -12.0%

DUE Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total, DUE	**$232.29**	**-**	**$204.39**	**-$27.90**	**-12.0%**
Learning and Learning Environments	**100.02**	**-**	**91.50**	**-8.52**	**-8.5%**
EHR Core Research (ECR): STEM Learning	13.02	-	4.50	-8.52	-65.5%
Improving Undergraduate STEM Education (IUSE)	87.00	-	87.00	-	-
STEM Professional Workforce	**132.08**	**-**	**112.89**	**-19.19**	**-14.5%**
Advanced Technological Education	66.04	-	59.00	-7.04	-10.7%
NSF Innovation Corps (I-Corps™)	1.55	-	-	-1.55	-100.0%
Robert Noyce Teacher Scholarship Program	64.50	-	53.89	-10.61	-16.4%

The Division of Undergraduate Education (DUE) supports the design, development, and study of innovative STEM learning environments that integrate cutting-edge science and education findings to improve learning for all undergraduates. These investments promote changes in teaching practices across the full range of U.S. higher education, from community colleges, through four-year colleges and large comprehensive public institutions, to research universities, including flagship state-supported systems. In turn, these changes serve to open multiple career pathways for undergraduates. For example, innovative efforts at community colleges enable students to gain expertise in advanced technologies such as additive manufacturing, biotechnology, precision agriculture, nano-optics, or cybersecurity that lead directly to employment in those sectors. At other institutions STEM majors can pursue alternative teaching certification to be able to enter the K-12 teaching workforce in high-need school districts. Overall, improved student learning outcomes for STEM students lead to greater retention and degree attainment, and better preparation to meet STEM-savvy workforce needs and to replenish the pool of future STEM researchers.

The FY 2018 Budget Request for DUE is $204.39 million. This budget will allow DUE programs to provide direction for the nationwide movement to transform undergraduate STEM education through the creation 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] 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. 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.

To increase the population of diverse, innovative STEM and STEM-savvy workers, DUE also will focus on improving the preparation of future members of two important sectors of the professional workforce: K-12 teachers and highly skilled technicians in advanced technology industries. In FY 2018, special attention will be placed on attracting proposals to IUSE: EHR led by investigators from minority-serving community colleges, as well as investigators from two- and four- year institutions with prior funding from HBCU-UP and TCUP. DUE funding for IUSE includes support for IUSE: HSI. 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 also be emphasized.

FY 2018 Summary

All funding decreases/increases represent changes over the FY 2016 Actual.

Learning and Learning Environments

- ECR: STEM Learning Environments (-$8.52 million to a total of $4.5 million): DUE has leadership for this ECR focus area. The funds 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.
- DUE's funding for IUSE is $87.0 million (level with FY 2016 Actual) to 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 seek to 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) within GRFP. 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 three 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 for 2-year and 4-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

- ATE (-$7.04 million to a total of $59.0 million) and Noyce (-$10.61 million to a total of $53.89 million). In FY 2018, ATE activities will continue to fund research and development on effective preparation of advanced technology technicians, while Noyce will continue investing in teacher preparation. In addition, both programs will continue to emphasize the preparation of a diverse STEM workforce and will incorporate a focus on inclusion, in partnership with the NSF INCLUDES initiative.

[10] National Academies of Sciences, Engineering, and Medicine. (2016). *Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support diverse student pathways.* Committee on Barriers and Opportunities in Completing 2-Year and 4-Year STEM Degrees. S. Malcom and M. Feder, Eds. Board on Science Education, Division of Behavioral and Social Sciences and Education. Board on Higher Education and the Workforce, Policy and Global Affairs. Washington, DC: The National Academies Press. Retrieved from https://www.nap.edu/catalog/21739/barriers-and-opportunities-for-2-year-and-4-year-stem-degrees

H-1B NONIMMIGRANT PETITIONER FEES $100,000,000

In FY 2018, H-1B Nonimmigrant Petitioner Fees are projected to be $100.0 million.

H-1B Nonimmigrant Petitioner Fees Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2018 Request Change Over FY 2017 Estimate	
				Amount	Percent
H-1B Nonimmigrant Petitioner Fees Funding	$184.89	$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).

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.

- **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 7,400 proposals from all types of colleges and universities and has made awards to 1,743 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 2018, 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 2018, with an emphasis on increasing involvement of community colleges, especially Hispanic-serving institutions. S-STEM activities in FY 2018 will leverage efforts in the IUSE: EHR and 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. 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).

- **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 U.S. 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.

  Since its inception, the ITEST program has received 4,961 proposals and funded 484 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. In FY 2018, ITEST will be a partner in the NSF INCLUDES initiative and will make approximately 20 awards.

H-1B Financial Activities from FY 2007 - FY 2016

(Dollars in Millions)

	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Receipts	**$107.36**	**$104.43**	**$88.66**	**$91.22**	**$106.11**	**$128.99**	**$120.94**	**$132.49**	**$143.00**	**$138.79**
Unobligated Balance start of year	**$98.19**	**$63.37**	**$50.83**	**$52.62**	**$50.15**	**$60.93**	**$99.31**	**$104.76**	**$108.35**	**$116.02**
Appropriation Previously unavailable (Sequestered)								**$5.10**	**$9.54**	**$7.30**
Appropriation Currently unavailable (Sequestered)								**-$9.54**	**-$7.30**	**-$6.80**
Obligations incurred:										
Scholarships in Science, Technology, Engineering, and Mathematics[1]	100.04	92.40	61.22	75.96	77.67	72.57	83.98	92.18	109.34	140.54
Private-Public Partnership in K-12[1]	45.90	28.72	27.86	20.85	18.62	21.59	31.51	37.23	29.83	44.35
Total Obligations	**$145.94**	**$121.12**	**$89.08**	**$96.81**	**$96.29**	**$94.16**	**$115.49**	**$129.41**	**$139.17**	**$184.89**
Unallocated Recoveries			2.20	3.12	0.96	3.55	-	4.95	1.60	4.20
Unobligated Balance end of year	**$59.61**	**$46.68**	**$52.62**	**$50.15**	**$60.93**	**$99.31**	**$104.76**	**$108.35**	**$116.02**	**$74.63**

[1] 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, and math and science teacher professional development.

Explanation of Carryover

Within the **H-1B** no-year account, $74.63 million was carried over into FY 2017.

Innovation Technology Experiences for Students (ITEST)

- Amount: $18.66 million
- Reason: 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 2017 Quarter 4

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)

- Amount: $55.97 million
- Reason: 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 2017 Quarter 4

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

$182,800,000
-$58,700,000 / -24.3%

Major Research Equipment and Facilities Construction Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Major Research Equipment and Facilities Construction	$241.50	$193.12	$182.80	-$58.70	-24.3%

The Major Research Equipment and Facilities Construction (MREFC) account supports the acquisition, construction, and commissioning of major research infrastructure 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 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate
DKIST	$20.00	$20.00	$20.00	$16.13	-	-	-	-
LSST[1]	92.97	67.12	57.80	48.82	46.34	40.75	5.36	-
NEON[2]	128.51	-	-	-	-	-	-	-
NEON transfers[3]	*[20.00]*	*[15.58]*	-	-		-	-	-
RCRV[4]	-	106.00	105.00	44.50	-	-	-	-
Enhanced Oversight	0.02	-	-	1.00	1.00	1.00	1.00	1.00
Total	**$241.50**	**$193.12**	**$182.80**	**$110.45**	**$47.34**	**$41.75**	**$6.36**	**$1.00**

[1] Of the $99.67 million appropriated for LSST in FY 2016, $6.70 million was carried over to FY 2017 and is excluded in the amounts above. This is being held as part of NSF's enhanced oversight of budget contingency.

[2] Of the $80.64 million appropriated for NEON in FY 2016, $8.40 million was carried over to FY 2017 and is excluded in the amounts above. This is being held as part of NSF's enhanced oversight of budget contingency as well as NSF-held management reserve.

[3] In June 2016, the National Science Board (NSB) approved an increase in NEON's Total Project Cost from $433.72 million to $469.30 million. The $35.58 million increase is provided through transfers from the R&RA account to the MREFC account of $20.0 million from FY 2016 funds (completed) and up to $15.58 million from FY 2017 funds (expected). The $20.0 million transferred in FY 2016 was carried over to FY 2017.

[4] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV. This will impact funding requirements for FY 2017, FY 2019, and FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

Modern and effective research infrastructure is critical to maintaining U.S. international 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 2018, NSF will request $182.80 million to continue construction on three of the four on-going projects; the Daniel K. Inouye Solar Telescope (DKIST), the Large Synoptic Survey Telescope (LSST), and the Regional Class Research Vessels (RCRV). NEON will be completed in spring 2018 with funds already appropriated per the table above. For more information on each project, 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 infrastructure such that approved budgets are sufficient to accomplish the scientific objectives. The current policy as published in NSF's Large Facilities Manual (LFM) requires that (1) the total project cost estimate when exiting the preliminary design phase includes adequate contingency to cover foreseeable risks, (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, and (3) if the project is approved to continue and further scope reductions become too detrimental to science, then the first 10 percent of any cost increase must be covered by the sponsoring directorate through R&RA funding. This final step was required for NEON, as noted in the table above and described in the individual narrative for the project.

All projects funded through the MREFC account undergo periodic cost, schedule, and risk reviews as required by the LFM and the terms and conditions of the cooperative agreements. NSF policies and reporting requirements are designed to ensure routine and reliable tracking of progress (including the use of Earned Value Management), project spending, and use of contingency and that program and recipients each have sufficient oversight and management authority (respectively) to meet project objectives.

Enhanced NSF Oversight

NSF has greatly strengthened its oversight of major facility projects in recent years, with a number of those enhancements now codified in the American Innovation and Competitiveness Act (AICA) of 2017. One significant enhancement is holding a portion of budget contingency (up to 100 percent) and only allocating to the program for obligation to the project based on demonstrated need. This oversight mechanism will generally result in some MREFC carryover each year; however, future obligation is anticipated to manage project risks. Enhanced oversight of the construction stage now also includes mandatory incurred cost audits and independent cost estimates, as well as other audits and reviews based on an annual major facility portfolio risk assessment. These efforts are conducted by NSF and are generally not attributable to a specific project at the time of budget formulation, nor are they part of the total project cost developed and managed by the recipient. To properly support and transparently account for these efforts, actual costs and future estimates for "Enhanced Oversight" are shown separately from each project in the MREFC account table. Initial funding (FY 2017 and FY 2018) for enhanced oversight activities is $500,000 to $1.0 million annually. These activities are supported with funds recovered from projects completed in previous years.

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,~~*$182,800,000*, to remain available until expended.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Major Research Equipment and Facilities Construction
FY 2018 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 2016 Appropriation	$200.31	$58.06	-$37.21	$2.34	18.00	$241.50
FY 2017 Annualized CR	199.93	37.21			-	237.14
FY 2018 Request	182.80					182.80
$ Change from FY 2017 Annualized CR						-$54.34
% Change from FY 2017 Annualized CR						-22.9%

Explanation of Carryover

Within the **Major Research Equipment and Facilities Construction** no-year account, $37.21 million was carried over into FY 2017.

National Ecological Observatory Network (NEON)
- Amount: $28.41 million
- Reason: FY 2016 obligations were limited due to construction management transition. For additional information, please see the NEON section of the MREFC Chapter.
- Obligated: FY 2017 Quarter 1

Large Synoptic Survey Telescope (LSST)
- Amount: $6.70 million
- Reason: These funds reflect updated NSF policy for the oversight of contingency, as discussed in the Enhanced Oversight section above.
- Anticipated Obligation: TBD - Funds held in reserve until needed.

The remaining $2.10 million is from completed projects. These projects are Ocean Observatories Initiative, Atacama Large Millimeter Array, South Pole Station Modernization, Advanced Laser Interferometer Gravitational Wave Observatory, and Large Hadron Collider. A portion of these carryover funds will be used for the enhanced oversight of MREFC projects.

The MREFC Account in FY 2018

The following narratives present detailed information on NSF's ongoing projects in FY 2018, with the sponsoring organization noted in parenthesis.

Daniel K. Inouye Solar Telescope, DKIST (MPS)………………………………......................MREFC – 4
Large Synoptic Survey Telescope, LSST (MPS)…………………………………...................MREFC – 10
National Ecological Observatory Network, NEON (BIO)……………………..........................MREFC – 15
Regional Class Research Vessel, RCRV (GEO).............………………………........................MREFC – 21

DANIEL K. INOUYE SOLAR TELESCOPE $20,000,000

The FY 2018 Budget Request for NSF's Daniel K. Inouye Solar Telescope (DKIST) is $20.0 million. This represents the 10th year in an 11-year funding profile, with an estimated total project cost of $344.13 million. Completion of construction atop Haleakala on Maui, Hawaii is planned for no later than June 2020.

When completed, 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 2014 Actual	FY 2015 Actual	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	Total Project Cost
MREFC Approp.	$60.00	$36.88	$25.12	$20.00	$20.00	$20.00	$16.13	$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	146.00
Total, DKIST	**$206.00**	**$36.88**	**$25.12**	**$20.00**	**$20.00**	**$20.00**	**$16.13**	**$344.13**

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, which determined that 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 appropriated to initiate construction. Funding was provided through a combination of the MREFC account ($7.0 million) and the American Recovery and Reinvestment Act (ARRA) account ($146.0 million). 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.

[1] www.nap.edu/catalog.php?record_id=12951
[2] www.nap.edu/search/?term=13060&x=0&y=0

The environmental compliance requirements were completed on November 20, 2009, and the NSF Director signed the Record of Decision authorizing construction 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. The Hawaii BLNR approved 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. The U.S. Fish and Wildlife Service completed a formal consultation regarding the endangered Hawaiian petrel in 2011. A contested case challenge to the 2010 CDUP issuance delayed site construction until the BLNR ruled in favor of the DKIST project and issued a new CDUP 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. An external panel of experts reviewed the revised baseline and increased the total project cost by approximately $46.20 million. The NSB also subsequently considered and approved a revised total project cost of $344.13 million at their August 2013 meeting.

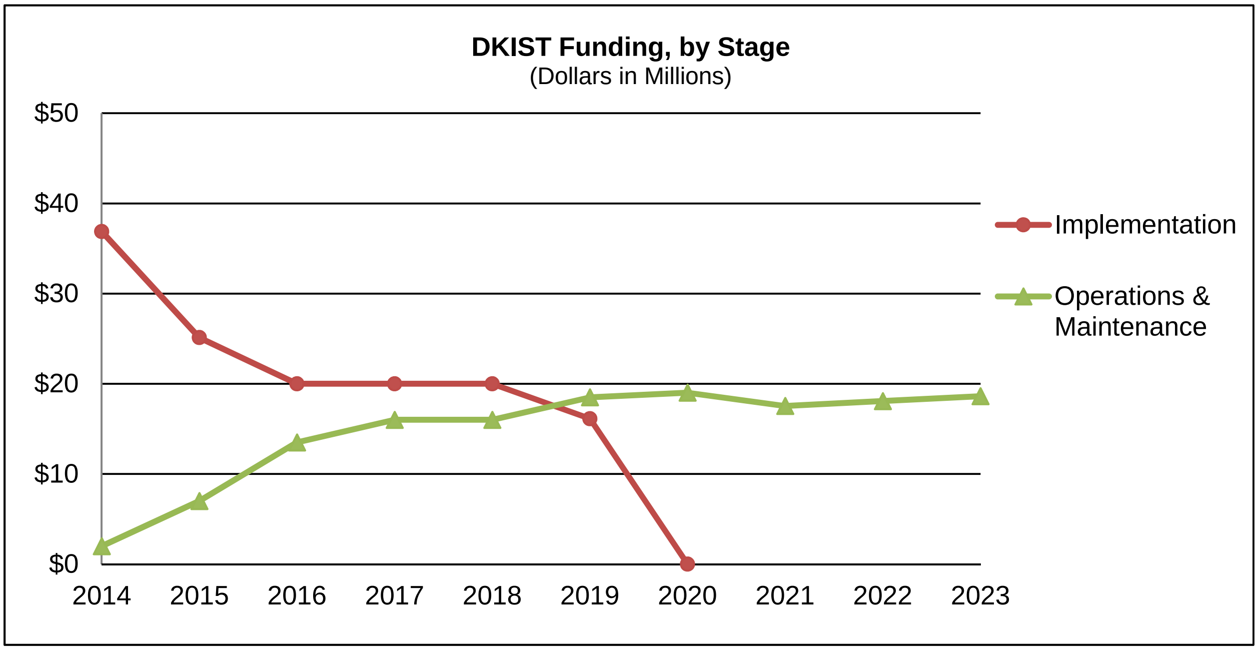
Total Funding Requirements for DKIST

(Dollars in Millions)

	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]	7.00	13.50	16.00	16.00	18.50	19.01	17.54	18.08	18.62
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	$30.51	$13.50	$16.00	$16.00	$18.50	$19.01	$17.54	$18.08	$18.62
MREFC:									
Implementation	122.00	20.00	20.00	20.00	16.13	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	$268.00	$20.00	$20.00	$20.00	$16.13	-	-	-	-
TOTAL REQUIREMENTS	**$298.51**	**$33.50**	**$36.00**	**$36.00**	**$34.63**	**$19.01**	**$17.54**	**$18.08**	**$18.62**

[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 million per year for FY 2011 through FY 2020 is for cultural mitigation activities as agreed to during the compliance process.



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 activities to be performed through partnerships are:

- 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 eliminates 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.

Management and Oversight

- 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), the Office of General Counsel, and the Office of Legislative and Public Affairs. Within BFA the Large Facilities Office (BFA/LFO) provides advice 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 CSA for DKIST construction runs through the end of FY 2019. The NSO CA and O&M CSA were 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 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

- 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.
- Business Systems Review (BSR): NSF conducted a BSR covering AURA, NSO, and the DKIST project December 2015 – March 2016. Findings and recommendations from NSF's final report were conveyed to AURA on April 1, 2016, and AURA continues to resolve issues and implement recommendations from the report.
- Contingency Assessment: BFA/LFO and MPS/AST conducted a detailed assessment of the DKIST budget and schedule contingency, February 2016 – July 2016. The assessment found that management of contingency is in compliance with current NSF guidelines and requirements. The remaining project budget and schedule contingency appear to be adequate based on accepted industry standards at an 80 percent confidence level for an on-budget and on-time completion. Findings and recommendations from the final NSF report were conveyed to AURA on August 5, 2016. AURA continues to implement recommendations from the report, while NSF tracks its progress.
- Earned Value Management (EVM) System Review: BFA/LFO and MPS/AST conducted a review of the DKIST project's EVM system, September 20-22, 2016. The external reviewers verified the project's EVM system and conducted interviews with project management and individual cost account managers (CAMs) to validate the input estimates/data into the system. The evaluation team found that the EVMS has been effectively implemented and is being used to provide reliable project management information. The NSF formally accepted the project's EVMS in a notification dated Feb. 22, 2017.
- Software Quality Assurance (SQA) Assessment: BFA/LFO has engaged a contractor to perform an assessment of the DKIST Project's processes and procedures for producing the software systems to be delivered at DKIST first light. The SQA assessment will consist of a document desk review followed by an in-person meeting in June 2017.
- Independent Risk Assessment (IRA): BFA/LFO has engaged a contractor to perform an independent assessment of the project's remaining risks as DKIST enters the critical integration, testing and commissioning (IT&C) stage of construction. The IRA will consist of a document desk review followed by an in-person meeting in September 2017.
- Programmatic Review: A comprehensive programmatic review of the DKIST MREFC construction project will be conducted in Q4 of FY 2017. This external programmatic review will focus on the IT&C phase of construction.

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:

- The project continues to work on interior fit and finish items for the enclosure (dome) and the support and operations (S&O) building.
- Work continues on the critical facility thermal systems (FTS) despite some staffing challenges.
- The Coudé rotator platform assembly inside the enclosure is completed. The Coudé rotator platform is undergoing site acceptance testing expected to be completed in Q3 of FY 2017.

- Assembly of the telescope mount assembly (TMA) continues through FY 2017 into Q2 of FY 2018 (see picture).
- Fabrication of the DKIST first-light instruments continues through FY 2017.

In FY 2018 installation of the TMA will be completed, and commissioning and acceptance testing of the TMA underway. The installation of the telescope structure and mechanical controls will have begun. By the end of FY 2018 the installation of the M1 main mirror will be underway and the alignment of the mirror with the laser metrology system begun. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered to the site, assembled and will begin initial checkout.

Installation of the saddle sections of the DKIST telescope mount assembly (TMA), March 2017. *Credit: P. Jeffers, DKIST.*

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). A Monte Carlo analysis of the risk-adjusted project end date at the time of the project re-baseline indicated June 10, 2020 at an 80 percent Confidence Level (CL) for successful completion. The project is currently on track for a late 2019 end date.

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 an MOU between AURA and KIS, and therefore the fabrication risks for this instrument remain with the German institute. The VTF recently achieved a technical milestone regarding the precision of the optics. KIS is currently on track to deliver a de-scoped (single etalon) version of the instrument by DKIST first light. The DKIST project and the managing organization, AURA, continue to actively manage the situation. It should be noted that the cooperative support agreement between the NSF and AURA identifies four facility-class instruments (not including the VTF) to be delivered by the DKIST Project at the end of the MREFC construction phase. The Project is currently on track to deliver those four instruments.

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. The two outstanding legal appeals with the potential to impact project construction were resolved in favor of the DKIST project. On October 6, 2016 the Hawaiian Supreme Court ruled against the appellant in the two cases and upheld both the DKIST project’s conservation district use permit (CDUP) and the University of Hawaii’s Haleakala Observatory Management Plan. These decisions substantially reduce the risks to DKIST construction due to permitting issues.

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

DKIST operations are funded through the Research and Related Activities account (R&RA). (See the NSO narrative in the Facilities chapter for more information.) In FY 2018, the request of $16.0 million includes $14.0 million for the continuing ramp of DKIST operations and $2.0 million for cultural mitigation activities as discussed below.

The need for a Remote Operations Building (ROB) facility located on Maui was identified in the early stages of DKIST development. In FY 2015, the managing organization (AURA) demonstrated to NSF that construction of a dedicated ROB would result in significant savings to the federal government, compared to leasing space over the planned 45-year lifetime of DKIST. Thus, operations costs of DKIST for FY 2018 and beyond have been reduced by $500,000 annually as compared to the FY 2016 NSF Budget Request to Congress. In FY 2019, the estimated steady-state operations and maintenance cost will be $16.50 million, exclusive of the $2.0 million for cultural mitigation activities described below. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete.

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.

The DKIST telescope enclosure and Support and Operations building at the site on Haleakala, Maui, HI, March 2017. *Credit: D. Boboltz, NSF.*

LARGE SYNOPTIC SURVEY TELESCOPE $57,800,000

The FY 2018 Budget Request for the Large Synoptic Survey Telescope (LSST) is $57.80 million. This is the fifth 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 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	Total Project Cost
$27.50	$79.64	$99.67	$67.12	$57.80	$48.82	$46.34	$40.75	$5.36	$473.00

LSST is located in Chile and, when completed, 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 set by considering four key science areas:

- the physics of dark energy and dark matter.
- a census of small bodies in the solar system, including potentially hazardous Near Earth Objects.
- the structure and contents of the Milky Way galaxy.
- 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 will result in a comprehensive data set that will enable hundreds of fundamental astrophysical studies by the entire research community on these and other topics. Thus, LSST has the potential to advance every field of astronomical study, from the inner Solar System to the large-scale structure of the Universe.

Baseline History

LSST is a joint NSF/Department of Energy (DOE) project to build an instrument that was ranked the top large ground-based astronomy project by the National Research Council (NRC) 2010 Decadal Survey.[3]

Prior to NSF's construction award, NSF, DOE, and private (non-federal) partners invested over $130.0 million. About 70 percent supported design and development, and about 30 percent, from 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 risk.

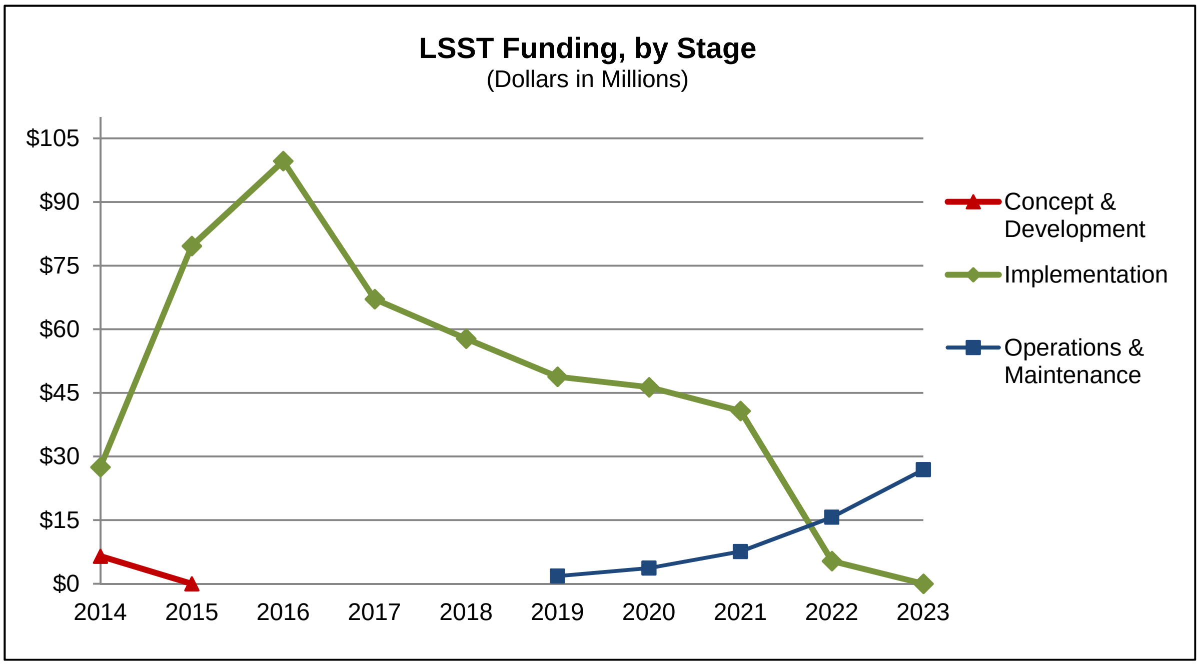
NSF and DOE conducted a series of reviews in 2011 and 2012 to determine the project baseline, including the NSF Preliminary Design Review (PDR) and a subsequent cost estimation review. Plans were kept up-to-date to synchronize the DOE and NSF funding profiles as reviews continued, leading to NSF's Final Design Review (FDR) in December 2013. NSF then carried out a detailed cost analysis prior to following through on its approval process and making an award in the last quarter of FY 2014.

[3] http://sites.nationalacademies.org/bpa/BPA_049810

Total Funding Requirements for LSST
(Dollars in Millions)

	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$57.13	-	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	1.80	3.70	7.60	15.70	26.90
Subtotal, R&RA	$57.13	-	-	-	$1.80	$3.70	$7.60	$15.70	$26.90
MREFC:									
Implementation[2]	107.14	99.67	67.12	57.80	48.82	46.34	40.75	5.36	-
Subtotal, MREFC	$107.14	$99.67	$67.12	$57.80	$48.82	$46.34	$40.75	$5.36	-
TOTAL REQUIREMENTS	**$164.27**	**$99.67**	**$67.12**	**$57.80**	**$50.62**	**$50.04**	**$48.35**	**$21.06**	**$26.90**

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.
[2] Includes $6.70 million carried forward into FY 2017.



LSST Science Plan

The site at Cerro Pachón, Chile was selected for LSST 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 changing and transient objects within 60 seconds of their discovery. Repeated deep imaging of every part of the accessible sky will turn up explosive events such as cataclysmic variable stars, supernovae, and the optical counterparts of X-ray flashes, as well as finding moving objects and better characterizing those already known. Early estimates of LSST’s ability to locate Near Earth Objects (NEO) and Potentially Hazardous Asteroids (PHA) have been refined by LSST Project members, as well as by external studies, including an independent Jet Propulsion Laboratory study supported by NASA’s Planetary Defense Coordination Office. Assuming other existing NEO efforts continue, at the end of LSST’s 10-year prime mission, the catalog should be ~75 percent complete for NEO (~80 percent for PHA), approximately 15 percent more complete than without LSST.

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 an 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 an MOU signed in July 2012.
- External Structure: The responsible awardee for LSST construction is the Association of Universities for Research in Astronomy, Inc. (AURA), a non-profit science management corporation consisting of 42 U.S. institutional members and five international affiliates. AURA works closely with the 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 construction; 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 NSF and DOE.

Reviews

- Technical Reviews: Reviews were conducted throughout the design and development phase, culminating in NSF's 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.
  - Major reviews held by both NSF and DOE prior to the MREFC award found the Basis of Estimate documentation to be quite adequate, with small improvements requested.
  - On May 7, 2014, the National Science Board (NSB) issued Resolution NSB-14-24, authorizing NSF management to proceed with the construction award, subject to additional cost and management scrutiny. Those reviews were carried out by NSF and allowed the MREFC award to be issued in August 2014.
  - The first annual construction review was scheduled for August-September 2015 but was deferred until February 2016. The review panel made several recommendations to improve project execution. To get back on schedule, the second progress review happened in August 2016 and was also successful, except that the Data Management (DM) systems were undergoing a major replan and could not be fully evaluated. A follow up intensive DM-focused review is being scheduled for July 2017. The next overall progress review is scheduled for September 2017.
  - In conjunction with the first progress review, NSF organized an Earned Value Management (EVM) validation review to consider both the adequacy of the system used for EVM, and the Project staff's ability to use EVM tools and methods. The Project passed with only minor recommendations for small improvements.

  - In January 2017, DOE and NSF held a joint external agency review of the project's plans for commissioning and transition to early operations.
- After 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 2015 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. Since then, the project has worked closely to the planned schedule and cost, with only minor issues covered from the (risk-based) contingency funds and by the use of internal contractor float and project schedule contingency. During FY 2017, the primary telescope building will be substantially completed, as will dome installation. The base facility reconstruction including the LSST Chilean data centers will be well underway, and the calibration telescope will be made ready for installation. NSF- and DOE- supported activities remain tightly coordinated, both at the project level and between agency program officers.

Cost and Schedule

A complete re-estimate of the project occurred 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. NSF carried out some further cost review prior to making the award.

NSF policy changed from a probabilistic contingency estimation based on the Project Management Control System (PMCS) to requiring a joint cost and schedule Monte Carlo (MC) method. The project established the new MC method throughout their PMCS and showed that the computed TPC corresponds to a better than 90 percent chance of coming in and within the cost sum of base plus contingency, and before the planned survey start date (base completion date plus schedule contingency). This result was finalized in April 2015 and incorporated into NSF's award instrument.

NSF has revised its policy on the use and oversight of management fees. AURA and NSF will carry out fee negotiations each fiscal year, and the total will fit under the approved total project cost. Because of these contingency and fee changes, the forward-projected budget profile has been revised.

In addition to NSF's contribution, DOE's baseline for the camera has been fixed at $168.0 million. Construction also includes $38.97 million from non-federal sources, all of which has been expended.

Risks

Technical: Much of the technical risk was retired during design and development. Since full construction began, no new major risks have appeared, and small, realized risks have been mitigated by use of cost and schedule contingency, including float internal to sub-projects. The Data Management construction effort currently is undergoing re-planning, and thus is being carried as a risk.

Environmental and Cultural Compliance: Environmental and cultural impact mitigation continues as planned with no unforeseen issues.

Site: The possible site risk due to local geological anomalies, mentioned in previous requests, was realized early during excavation. Since this risk was localized and anticipated, it was successfully handled. Site disruptions from geological events and extreme weather remain as possible risks with appropriate mitigation plans.

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. Both the summit and base sites have on-site safety supervisors employed by LSST to monitor contractor and project activities. All safety plans are fully compliant with applicable standards from U.S., Chilean, and participating institutions, and are updated regularly. External reviews have given the Project high marks for its safety culture.

Partnership Risk: The LSST project director and deputy oversee the entire project. A single project manager, agreed to by both NSF and DOE, manages the complete work breakdown structure elements. 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.

Future Operations Costs

Operation costs will be funded out of the Research and Related Activities account. The current estimate for full operations costs was $36.63 million per year (US$ FY 2013) at the time of FDR. The final full operations costs and the amount required from non-federal partners will be determined through a review and approval process scheduled to start in mid-2017 when the project submits a formal proposal for LSST operations jointly to NSF and DOE.

In their joint MOU, NSF and DOE agreed to fund operations, increasing agency support and/or revising the operations plans, as appropriate. MPS/AST has been planning to provide half of the original amount plus early operations support, with the DOE Office of High Energy Physics providing one quarter. The project team has already established firm agreements to fund ~$6.3 million of the estimated $9.0 million annual operating costs allocated for funding by non-federal entities, and negotiations continue with potential partners to find the remaining balance. Should full funding of the operations budgets not be achieved, the project has also prepared de-scope plans that reduce the scope of operations but also inevitably affect some of the science deliverables. Although the possibility of insufficient operational funding is not a risk to the project, it is a significant concern for the agencies and the awardee and is being closely watched.

Construction status on Cerro Pachón, February 2017. *Credit: LSST.*

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK $0

No MREFC funds are requested for the National Ecological Observatory Network (NEON) in the FY 2018 Request. Construction funding totals an estimated $469.30 million, which reflects a $35.58 million increase in the Total Project Cost (TPC) in conjunction with the change in the managing organization. The increase in the TPC is being funded via transfers of Research and Related Activities (R&RA) funds from the Directorate for Biological Sciences (BIO). Construction is expected to be complete by the spring of 2018. NEON operations and maintenance will be funded through the R&RA account.

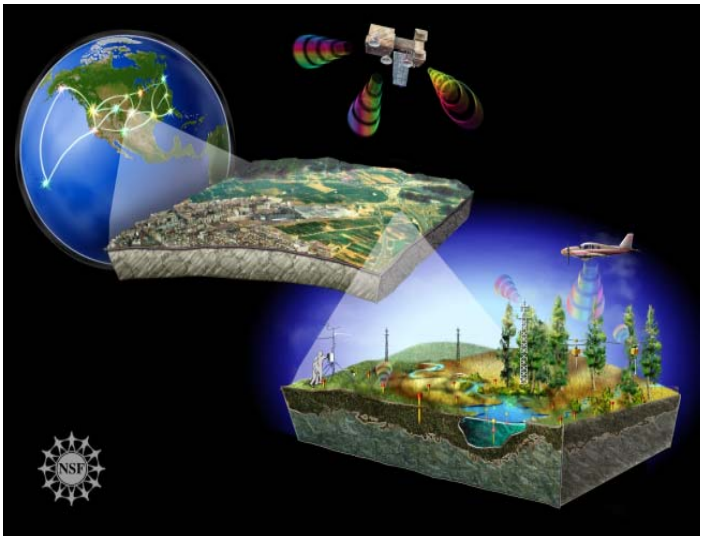
Appropriated and Requested MREFC Funds for the National Ecological Observatory Network

(Dollars in Millions)

	Prior Years	FY 2012 Actual	FY 2013 Actual	FY 2014 Actual	FY 2015 Actual	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	Total Project Cost[1]
Previous Funding Profile	$12.59	$60.30	$91.00	$93.20	$96.00	$80.64	-	-	$433.72
Revised Funding Profile	12.59	60.30	91.00	93.20	96.00	100.64	15.58	-	469.30
Change from Previous Profile	-	-	-	-	-	*20.00*	*15.58*	-	*35.58*

[1] In June 2016, the National Science Board (NSB) approved an increase in NEON's Total Project Cost from $433.72 million to $469.30 million. The $35.58 million increase is provided through transfers from the R&RA account to the MREFC account of $20.0 million from FY 2016 funds (completed) and up to $15.58 million from FY 2017 funds (expected).

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.



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.*

Baseline History

In 2004, the National Research Council 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 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.

Total Funding Requirements for NEON

(Dollars in Millions)

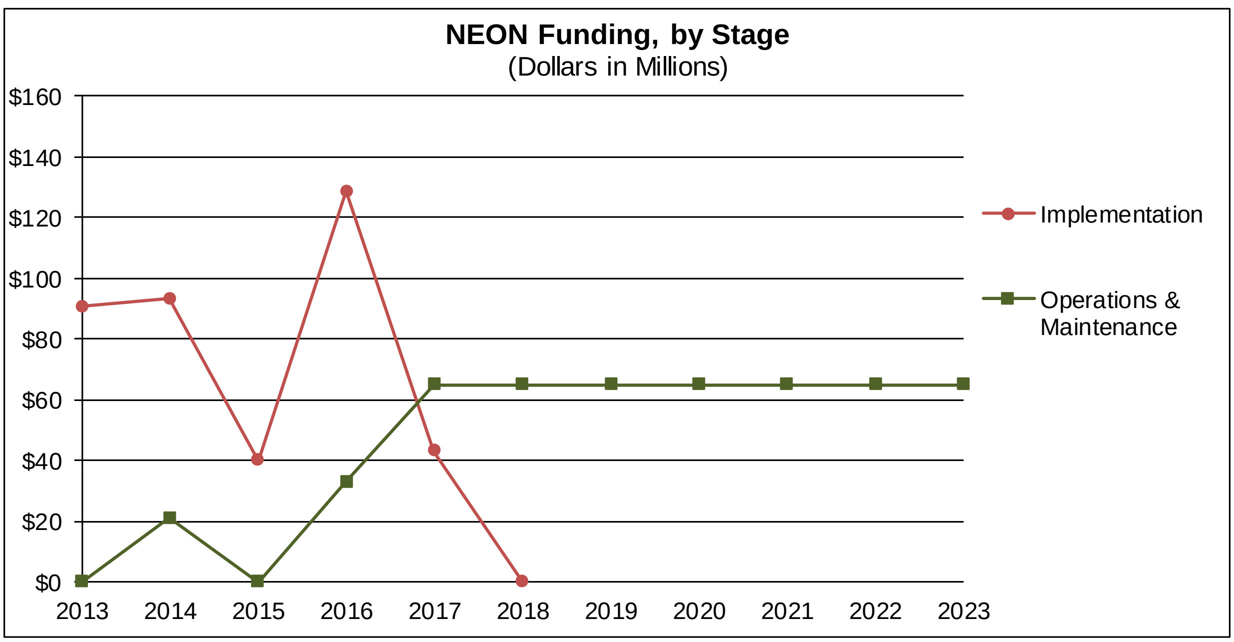
	Prior Years[1]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$104.85	-	-	-	-	-	-	-	-
Operations & Maintenance[2,3]	21.00	32.97	65.00	65.00	65.00	65.00	65.00	65.00	65.00
ARRA	9.96	-	-	-	-	-	-	-	-
Subtotal, R&RA	$135.81	$32.97	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00	$65.00
MREFC:									
Implementation[3,4]	296.88	128.51	43.91	-	-	-	-	-	-
TOTAL REQUIREMENTS	**$432.69**	**$161.48**	**$108.91**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**	**$65.00**

[1] Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance (O&M) funding reflects prior year actual obligations only.

[2] Funding for O&M is currently capped at $65.0 million per year for planning purposes, pending the results from an initial period of operations under Battelle management. Future O&M requests will be based on a more thorough analysis of science capabilities and affordability.

[3] Consistent with revised TPC plans, $20.0 million of FY 2016 R&RA appropriated funding was transferred to the MREFC account and carried forward into FY 2017. Up to $15.58 million of FY 2017 R&RA requested funding is expected to be transferred into the MREFC account.

[4] $56.0 million of FY 2015 MREFC funding for NEON was carried over into FY 2016. A total of $28.41 million of FY 2016 MREFC funding was carried over into FY 2017 of which $8.40 million is being held as part of NSF's strengthened oversight of budget contingency as well as NSF-held management reserve. These funds will be made available to the project based on bona fide need and recipient performance.



Note: In FY 2016, $20.0 million was transfered from the R&RA account to the MREFC account for NEON Implementation. In FY 2017, a transfer of up to $15.58 million from the R&RA account to the MREFC account is expected.

MREFC Project Plan

NEON is the first research platform and the only national experimental facility specifically designed to collect consistent and standardized sensor and biological measurements across 81 sites nationwide; reduced from 106 sites following NSF's decision in FY 2015 to de-scope the project in order to prevent a potential $80.0 million cost overrun. Measurements will enable 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 continental-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 Battelle Memorial Institute, 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 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 environmental 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 memorandums of understanding 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.

<u>Management and Oversight</u>

- NSF Structure: The NEON program is managed by the Division of Biological Infrastructure (DBI) within BIO. Managing the NEON program in DBI helps foster its associations with other BIO facilities and infrastructure investments and its connections to broader biological and interdisciplinary science activities. Within BIO/DBI, a Science Advisor (working with the Deputy Division Director) provides

[4] Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson (Eds.). (2009). *Global Climate Change Impacts in the United States.* Retrieved from https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

[5] The U.S. National Plan, 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.' National Science and Technology Council, Executive Office of the President. (2014). *National Plan for Civil Earth Observations*. (p. 71). Retrieved from www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf

[6] Group on Earth Observations. (2005, February). *Global Earth Observation System of Systems (GEOSS): 10-Year Implementation Plan*. Retrieved from www.earthobservations.org/documents/10-Year%20Plan%20Reference%20Document.pdf

overall programmatic oversight for BIO's mid- and large-scale research infrastructure, while the day-to-day program management is done by dedicated cognizant program officers with assistance from a program manager experienced with other MREFC projects. The cognizant program officers for construction and operations coordinate the direct oversight of NEON construction, operations and maintenance, and science utilization. An NSF Integrated Project Team (IPT) chaired by the NEON program officers, with representatives from the Office of Budget, Finance, and Award Management which includes the Large Facility Office, the Office of Legislative and Public Affairs, the Office of the Director , and program representatives from other NSF large facilities, helps ensure 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.

- External Structure: NEON, Inc., the company previously managing the NEON project, was notified in December 2015 of NSF's intent to transfer responsibility for construction and initial operations to a new management entity. In 2016, NSF used an expedited process to select a new managing entity for the NEON construction and initial observatory operations. As of June 2016, the NEON project is now fully managed by Battelle Memorial Institute, Inc. (Battelle), a non-profit, membership-governed corporation with extensive experience managing large research projects, government contracts, and related activities.

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.
- NSF conducted a Readiness Review to assess Battelle's competence to assume management of the NEON project in June of 2016.
- Construction, Cost, and Schedule reviews:
  - 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 $80.0 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.
  - In July 2015, NSF directed NEON, Inc. to reduce the project scope and deliver revised project documents, construction schedule, and cost proposal to reflect the scope reduction.
  - A revised proposal was submitted December 2015 which indicated the potential for an additional $19 million cost overrun and further schedule slip leading NSF to make its decision to transfer management responsibility.
  - An independent cost estimate (ICE) was obtained by NSF to support its internal cost analysis and award to the new managing organization.
  - In June 2016 NSF conducted a site visit in order to review Battelle's readiness to assume full responsibility for the remaining construction and initial operations of the NEON Observatory.
  - A Construction and Transition to Operations Review will be conducted in 2017.
- National Science Board (NSB) Review: The NSB reviewed and authorized NEON construction in May 2010 and authorized initial NEON Operations and Maintenance (O&M) in February 2013. In

September 2015, it established an ad hoc Task Force on NEON Performance and Plans to review and monitor NSF's oversight of the project. In 2016, after review of a new construction cost proposal (including the ICE), Battelle's successful management of the project to-date, and the remaining project risks, the NSB authorized an increase in the total project cost from $433.72 million to $469.30 million.

- Management, Business, and Operations Reviews:
  - NSF conducted a Business Systems Review 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.
  - Delays in construction have impacted rollout of operations by one year. With the transition to Battelle, an extension of the initial operations award is anticipated to allow the project to stabilize. A focused, external review of annual operations costs is planned for March 2017. A pre-award cost review prior to full observatory operations funding is expected in FY 2018.
  - Annual Operations Reviews will continue once construction is complete.

Project Status

Eighty-five percent of the Observatory research capabilities have been achieved with one hundred percent capability planned to be completed by the spring of 2018. This includes construction for the remaining terrestrial locations, aquatic sites, and airborne observation platforms (AOP).

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. De-scoping decisions were finalized and implemented in late July 2015.

For FY 2017, $65.0 million was requested from the R&RA account to support initial operations and maintenance. This represents the final increment from the original three-year O&M award as well as a partial increment for a proposed two-year extension while future costs are evaluated by NSF. The additional two years in O&M will allow time for a more complete understanding of the science capabilities and costs proposed, identification of management efficiencies under Battelle, 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 cost. 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 AOP.

In FY 2018, NSF will explore options for O&M of the full NEON Observatory after construction. As noted above, NSF expects to extend the initial operations award that began in FY 2014 for 24 months to allow Battelle time to identify project efficiencies, minimize costs, and maximize science delivery. Final costs for observatory O&M will be determined on the basis of these management efforts and analyses.

Cost and Schedule

The original projected length of the construction stage was six fiscal years, with six-months of schedule contingency included. Project performance under NEON, Inc., was running well behind the original plan. Under Battelle's management, the planned project end date has shifted back to mid-FY 2018 and the TPC has been re-established as described above. Roughly 80 percent of the approved project funds for construction have been spent, with Observatory capability at approximately 85 percent complete. Focused management by Battelle and oversight by NSF is now required to remain within budget and on schedule.

Risks

Technical: 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. Technical risk is considered low at this point in construction. The remaining technical hurdle is deployment of the cyber-infrastructure architecture for full integration of the NEON observatory sites and mobile platforms for delivery of data to the science community.

Deployment: Environmental assessment and permitting continues to have a potential impact on schedule. Risk mitigation strategies include the direct contracting of the environmental assessments by NSF, the hiring of experienced, national firms by Battelle for engineering and permitting, and the identification of alternative sites if primary sites still hold significant risk. The selection of alternative sites for other high-risk sites is nearing completion and environmental compliance activities are actively underway.

Management: Management risk has been partially mitigated by NSF based on the decision to replace NEON, Inc. with Battelle. The transition to new management is an inherently risky proposition but was necessary in this case. Battelle continues to work closely with NSF oversight personnel to clearly communicate process, standards, timelines, costs, and expectations.

Future Operations Costs

NEON is the first research observatory that will maintain and operate in-situ instrumentation and conduct biological sampling in 20 domains (81 locations) including three airborne observatories, a central operating facility, and a cyberinfrastructure center. Field 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 activities and associated costs will ramp up as sites are commissioned. Battelle is accelerating the transition of infrastructure to operations whenever possible to appropriately manage construction costs.

A three-year initial award for O&M began September 2014 to allow NEON, Inc. to explore opportunities for schedule and cost efficiencies and provide a basis for funding the full Observatory operations during out-years. The delay in construction has extended this activity from FY 2016 through early FY 2018. An extension of the initial operating period through FY 2019 is now planned under Battelle to allow the project to stabilize. For FY 2018, O&M costs are capped at $65.0 million for planning purposes with final costs to be determined after Battelle's assessment of management efforts and analyses.

REGIONAL CLASS RESEARCH VESSELS $105,000,000

The FY 2018 Request for the Regional Class Research Vessel (RCRV) project is $105.0 million. This represents the second 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[1]
(Dollars in Millions)

FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	Total Project Cost
-	$106.00	$105.00	$44.50	$255.50

[1] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV which impacts funding requirements for FY 2017, FY 2019, FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

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*[7], 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).[8] 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

[7] The National Academies of Science. Sea Change: 2015-2025 Decadal Survey of Ocean Sciences, 2015. www.nap.edu/read/21655/chapter/1

[8] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013. https://obamawhitehouse.archives.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

construction of RCRVs. Oregon State University (OSU) was selected and received the award in 2013. Input from external review panels, the University-National Oceanographic Laboratory System (UNOLS), and the NAS *Sea Change* report were received during the period 2013 to 2015 which informed the final decision to pursue construction of two RCRVs. In 2015 the National Science Board authorized inclusion of funds to initiate construction of two RCRVs in future budget requests at the NSF Director's discretion. The Final Design Review was conducted in December 2016 and the panel recommended to NSF that the project be advanced to the construction stage.

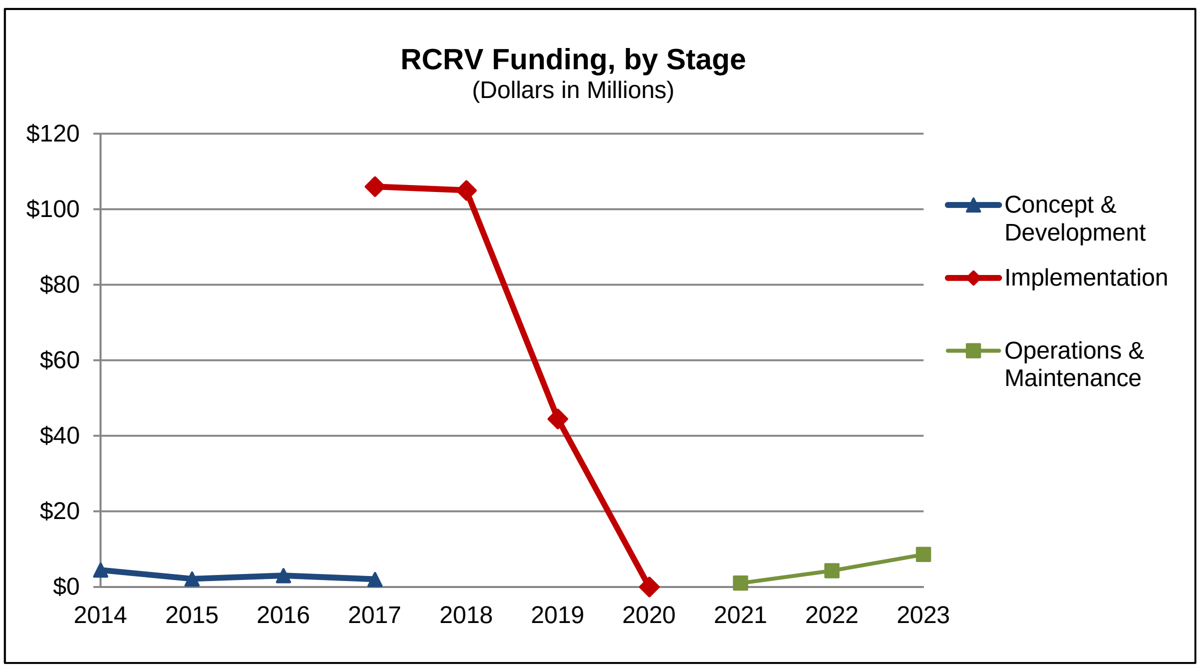
Total Funding Requirements for RCRV[1]

(Dollars in Millions)

	Prior Years[2]	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
R&RA:									
Concept & Development	$6.62	$3.09	$2.00	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	-	1.00	4.30	8.60
Subtotal, R&RA	$6.62	$3.09	$2.00	-	-	-	$1.00	$4.30	$8.60
MREFC:									
Implementation	-	-	106.00	105.00	44.50	-	-	-	-
Subtotal, MREFC	-	-	$106.00	$105.00	$44.50	-	-	-	-
TOTAL REQUIREMENTS	**$6.62**	**$3.09**	**$108.00**	**$105.00**	**$44.50**	**-**	**$1.00**	**$4.30**	**$8.60**

[1] This table does not reflect final action on FY 2017 appropriations, which were enacted too late to be incorporated in this document. P.L. 115-31 provided funding for an additional RCRV which impacts funding requirements for FY 2017, FY 2019, FY 2020, and the total project cost. There is no impact on the FY 2018 Budget Request.

[2] Concept & Development funding and Implementation funding are cumulative of all prior years.



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 administrative 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 (PI) for the award is the project manager (PM), who reports directly to the OSU Dean of the College of Earth, Ocean and Atmospheric Sciences. The PM interacts directly with NSF and manages the RCRV administrative staff. The project scientist (PS) is a co-Principal Investigator (PI) on the award. 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 independent 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. The SOC provides guidance to the OSU RCRV project team through the PM 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 was held in February 2016, at NSF. NSF directed OSU to make minor revisions to the Request for Proposals (RFP) based on the review.
- Interim Design Review (IDR): A second IDR was held 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 was warranted. The review was hosted by the RCRV Project Team in Corvallis, OR, and attended by NSF program staff as well as the RCRV SOC. The SOC provided minor technical improvements to the RCRV, which were incorporated into the RFP package.
- Final Design Review (FDR): The FDR was held in December 2016 to ensure that anticipated project costs remained realistic and that no unforeseen events had arisen prior to the start of construction during FY 2017. Several members of the PDR panel also participated in the FDR. Like CDR and PDR, FDR was conducted in compliance with NSF's Large Facilities Manual. The FDR Panel recommended to NSF that the project be advanced to the Construction Stage.

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 will complete Phase II in CY 2017, during which bids for construction of RCRVs are being solicited and evaluated from U.S. shipyards. Total funding to OSU for RCRV through FY 2017 is expected to be $11.39 million in R&RA funds and $106.0 million in MREFC funds.

Cost and Schedule

The projected length of the project is 10 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.

One significant enhancement to the management of contingency is holding a portion of budget contingency (up to 100 percent) and only allocating to the program, for obligation to the project, based on demonstrated need. This oversight mechanism will generally result in some MREFC carry over each year, however, future obligation is anticipated to manage project risks.

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: The desired low ship self-noise levels may not be initially achieved. Contingency funds are included if a secondary noise mitigation strategy is required to meet the ship specifications. Sonar sensors, science load handling systems, and other vessel sub-systems may also 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. A selected shipyard may 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 funds are 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 (ARF). 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 beginning in 2021 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 $6.10 million to operate in its first year, resulting in a rate of $30,441 per day, including technician support. 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 approximately $4.30 million in FY 2022, which is the first year the lead ship transitions into full operations in the ARF. 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. The second ship would transition to full operations in the ARF in FY 2023.

Artist’s rendition of the RCRV as constructed. *Credit: The Glosten Associates Inc.*

ORGANIZATIONAL EXCELLENCE $479,980,000
-$10,910,000 / -2.2%

Organizational Excellence Funding Summary

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$490.89	-	$479.98	-$10.91	-2.2%

NSF's FY 2018 funding for Organizational Excellence is $479.98 million. NSF's Strategic Plan for 2014-2018,[1] 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 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.

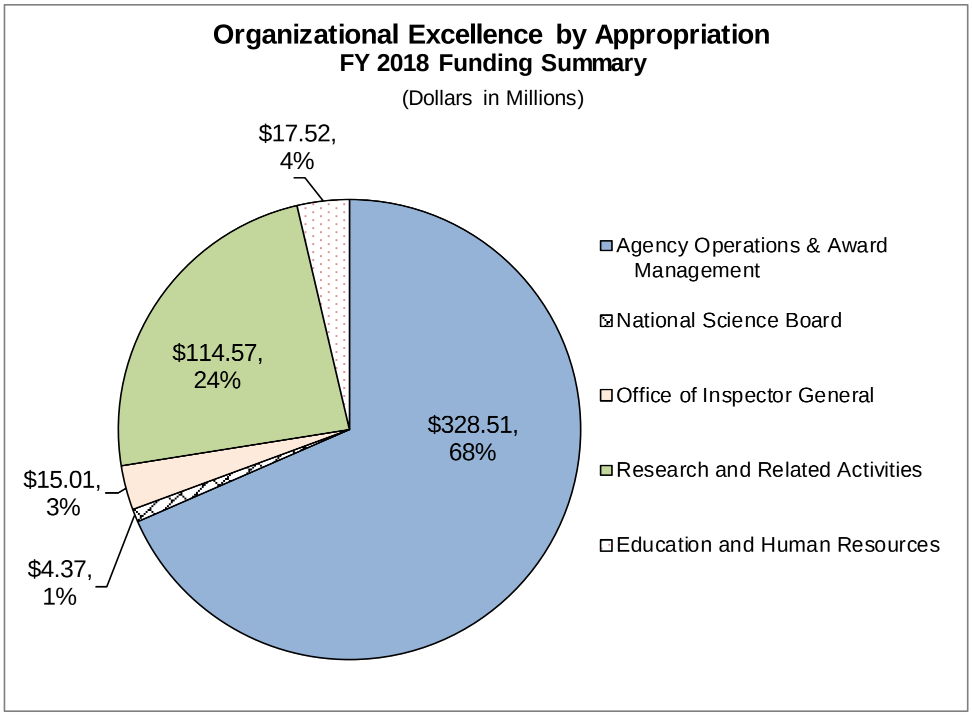
An overview of the various activities that are included in the Organizational Excellence portfolio is included in this summary. Also included in this discussion is information on the E-Government initiatives to which the agency contributes. The two tables on the following pages show first the Organizational Excellence portfolio by appropriation, and second the portfolio by its major components—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)—along with their funding sources, as several are funded through more than one appropriation.

Underlying the FY 2018 Budget Request is NSF's ongoing commitment to increase agency efficiency while constraining administrative costs; which is consistent with the Administration's commitment to manage programs and deliver critical services more effectively, devote a greater percentage of taxpayer dollars to mission achievement, and to be more effective and efficient in supporting program outcomes. 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 2016, two strategic reviews identified opportunities for action or improvement closely aligned with the Organizational Excellence portfolio of activities. The strategic reviews focused on the following Strategic Objectives: (1) Build an increasingly diverse, engaged, and high performing workforce by fostering excellence in recruitment, training, leadership, and management of human capital, and (2) Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission.

[1] NSF (2014). Investing in Science, Engineering, and Education for the Nation's Future – National Science Foundation Strategic Plan for 2014-2018. Retrieved from www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14043

NSF also has two performance goals aligned with the Organizational Excellence portfolio of activities: 1) Use Evidence to Guide Management Decisions and 2) Foster a Culture of Inclusion. More detail on the strategic reviews and NSF's performance goals can be found in the Performance chapter.



Organizational Excellence by Appropriation

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Agency Operations & Award Management	$351.11	-	$328.51	-$22.60	-6.4%
National Science Board	4.31	-	$4.37	0.06	1.5%
Office of Inspector General	14.76	-	$15.01	0.25	1.7%
Program Support:					
Research and Related Activities	106.12	-	$114.57	8.45	8.0%
Education and Human Resources	14.60	-	$17.52	2.92	20.0%
Subtotal, Program Support	*$120.72*	-	*$132.09*	*$11.37*	*9.4%*
Total	**$490.89**	**-**	**$479.98**	**-$10.91**	**-2.2%**

Organizational Excellence by Major Component

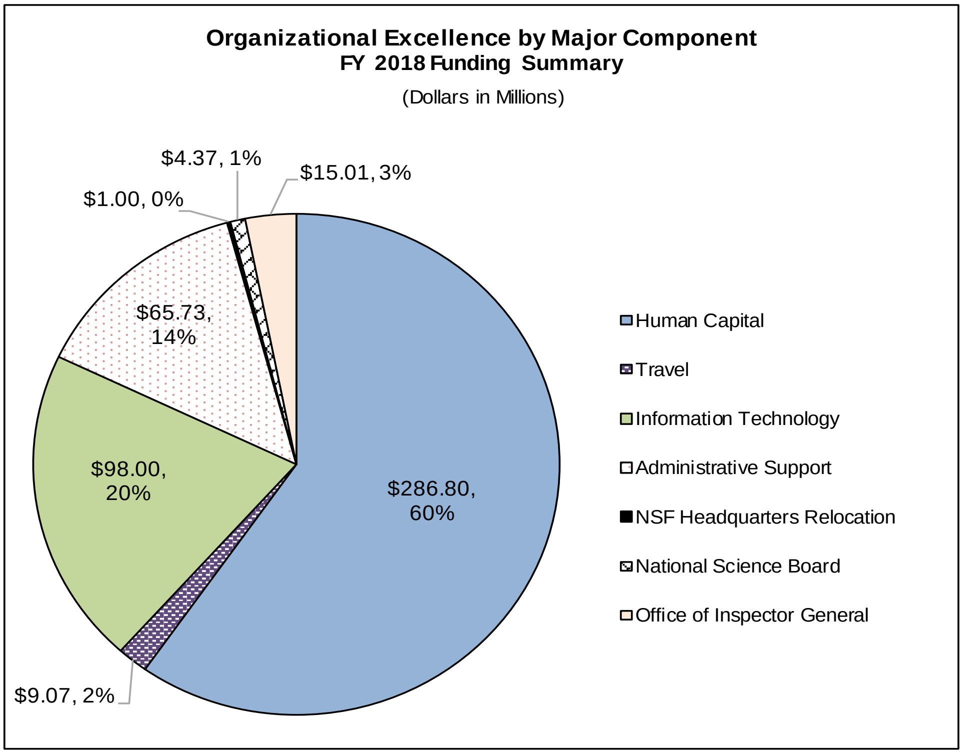
The table below shows the major components of Organizational Excellence. This table also shows the funding sources for the major components and activities, as several are funded through more than one appropriation.

Organizational Excellence by Major Component

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent	Funding Source
Human Capital	$261.27	-	$286.80	$25.54	9.8%	
Personnel Compensation & Benefits[1]	208.93	-	226.00	17.07	8.2%	AOAM
Management of Human Capital	10.09	-	10.11	0.01	0.1%	AOAM
IPA Appointments	42.25	-	50.70	8.45	20.0%	
Compensation	38.33	-	46.11	7.78	20.3%	RRA/EHR
Lost Consultant & Per Diem	3.92	-	4.59	0.67	17.1%	RRA/EHR
Travel	$8.83	-	$9.07	$0.24	2.7%	
NSF Federal Employee Staff	5.75	-	5.45	-0.30	-5.2%	AOAM
IPA Appointments	3.08	-	3.62	0.54	17.4%	RRA/EHR
Information Technology (IT)	$88.22	-	$98.00	$9.78	11.1%	
Agency Operations IT	21.94	-	25.28	3.34	15.2%	AOAM
Administrative Applications Services and Support	5.41	-	7.51	2.10	38.8%	AOAM
Administrative Infrastructure Services and Support	12.99	-	14.23	1.24	9.6%	AOAM
Administrative Security and Privacy Services and Support	3.03	-	3.03	-	-	AOAM
Administrative IT Management	0.51	-	0.51	-	-	AOAM
Program Related Technology (PRT)	66.28	-	72.72	6.44	9.7%	RRA/EHR
Mission-Related Applications Services	46.87	-	47.20	0.33	0.7%	RRA/EHR
Mission-Related IT Operations and Infrastructure	14.19	-	19.31	5.11	36.0%	RRA/EHR
Mission-Related Security and Privacy Services	2.98	-	3.98	1.00	33.4%	RRA/EHR
Mission-Related IT Management	2.24	-	2.24	-	-	RRA/EHR
Administrative Support	$73.63	-	$65.73	-$7.91	-10.7%	
Space Rental	33.37	-	27.75	-5.62	-16.8%	AOAM
Operating Expenses	17.35	-	19.83	2.47	14.2%	AOAM
Building and Administrative Services	13.81	-	13.10	-0.71	-5.1%	AOAM
Other Program Related Administration	9.10	-	5.05	-4.05	-44.5%	RRA/EHR
Evaluation and Assessment Capability	5.35	-	-	-5.35	-100.0%	RRA/EHR
Proposal Management Efficiencies	0.31	-	1.11	0.80	258.3%	RRA/EHR
E-Government Initiatives	1.01	-	1.46	0.45	45.2%	RRA/EHR
General Planning and Evaluation Activities	2.43	-	2.48	0.04	1.8%	RRA/EHR
NSF Headquarters Relocation	$39.87	-	$1.00	-$38.87	-97.5%	AOAM
National Science Board (NSB)	$4.31	-	$4.37	$0.06	1.5%	NSB
Office of Inspector General (OIG)	$14.76	-	$15.01	$0.25	1.7%	OIG
Total, Organizational Excellence	**$490.89**	**-**	**$479.98**	**-$10.91**	**-2.2%**	

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2016, $5.48 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $214.41 million. Approximately $5.82 million in ACRs are expected in FY 2018 to meet the total PC&B requirement of $231.81 million.



1. Human Capital: The FY 2018 funding amount for Human Capital is $286.80 million. The Human Capital component includes personnel compensation and benefits of NSF's federal employees as well as support for NSF's temporary employees**—**both those that are hired through authority provided by the Intergovernmental Personnel Act, known as IPAs, and those employed through NSF's own Visiting Scientist, Engineer, and Educator (VSEE) program. NSF's federal employee full-time equivalents (FTE) and VSEEs 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 VSEEs, 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. VSEEs count as regular federal FTE and are included in the regular AOAM FTE totals. IPAs are not included in the regular AOAM FTE totals.

NSF Workforce:
The table below the agency's total workforce for FY 2018.

NSF Workforce

Full-Time Equivalents (FTE)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual 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	1,276	-	1,310	34	2.7%
Pathways Interns [1]	34	-	42	8	23.5%
Subtotal, AOAM FTE	1,310	-	1,352	42	3.2%
Office of the Inspector General	67	-	69	2	3.0%
National Science Board	18	-	19	1	5.6%
Arctic Research Commission	3	-	3	-	-
Total, Federal Employees (FTE)	1,398	-	1,443	45	3.2%
IPAs (FTE)	183	-	199	16	8.7%
Detailees to NSF	3	-	3	-	-
Total, Workforce	**1,584**	**-**	**1,645**	**61**	**3.9%**

[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).

A discussion of NSF's FTE allocation and usage is included in the Personnel Compensation and Benefits (PC&B) 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 U.S. Arctic Research Commission (USARC) chapters include a discussion of their respective workforces.

The Human Capital component also includes support for the Management of Human Capital, which is discussed in the AOAM chapter.

2. Travel: For FY 2018, the request for staff and IPA travel is $9.07 million. Staff travel accounts for about 60 percent of this total; a request of $5.45 million in FY 2018 provided from the AOAM account. Travel for IPA appointments, which is supported by the R&RA and EHR accounts, is $3.62 million. For more detailed information about NSF staff and IPA travel funding, see the AOAM and Program Accounts: R&RA and EHR chapters, respectively.

3. Information Technology (IT): For FY 2018, IT investments total $98.0 million. Funding for NSF's IT investment is provided from the AOAM, R&RA, and EHR accounts.

IT Investments by Appropriation

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Agency Operations & Award Management	$21.94	-	$25.28	$3.34	15.2%
Program Related Technology	66.28	-	72.72	6.44	9.7%
Research and Related Activites	57.67	-	63.27	5.60	9.7%
Education and Human Resources	8.62	-	9.45	0.84	9.7%
Total	**$88.22**	**-**	**$98.00**	**$9.78**	**11.1%**

Agency 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 26 percent of NSF's total IT investment in the FY 2018 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 74 percent of NSF's FY 2018 Budget Request for IT investments. More information on PRT can be found in the Program Accounts: R&RA and EHR chapter.

4. Administrative Support: FY 2018 funding for Administrative Support is $65.73 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:

- Space Rental at $27.75 million. FY 2018 will be NSF's first year in its new headquarters building in Alexandria, Virginia. The FY 2018 space rental cost represents a decrease of $5.62 million from the rental cost last fiscal year in the previous NSF headquarters building. More detailed information about Space Rental can be found in the AOAM chapter.
- Operating Expenses ($19.83 million) includes funding for various financial and award management and leadership activities such as post-award monitoring; contract close-out activities; large facility oversight; improper payments, financial statement, and internal controls reporting; Committee on Equal Opportunities in Science and Engineering (CEOSE) activities; NSF'S Enterprise Information System; and supplies, equipment, and training which are necessary for the accomplishment of NSF's mission. A detailed discussion about Operating Expenses can be found in the AOAM chapter.
- Building and Administrative Services ($13.10 million) includes administrative contracts that support NSF's facilities and business operations, administrative services, and infrastructure such as security system maintenance, ID issuance, continuity of operations support services, and Federal Register notices for panels and advisory committees. A detailed discussion of these activities can be found in the AOAM chapter.
- Other Program Related Administration (PRA) is funded at $5.05 million to support general Planning and Evaluation activities, which include agency-wide efforts such as the verification and validation of performance information, E-Government efforts, and Proposal Management Efficiencies (PME). A detailed discussion about Other PRA can be found in the Program Accounts: R&RA and EHR chapter.

5. NSF Headquarters (HQ) Relocation: The FY 2018 Request is $1.0 million. NSF is anticipated to complete the move of its headquarters to the new building in Alexandria, VA by October 1, 2017. A small budget remains in FY 2018 for items such as decommissioning of the current headquarters buildings and unanticipated changes required at the new headquarters.

6. National Science Board (NSB): The staffing and operations of the NSB office are supported through a separate NSB appropriation. Details about the NSB FY 2018 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. Details about the OIG FY 2018 Budget Request can be found in the OIG chapter.

NSF FY 2018 Request Submission Funding for E-Government Initiatives

The tables below show NSF's contributions and service fees for various E-Government initiatives. This level is consistent with the FY 2018 funding amounts provided by the initiatives' respective managing partners.

NSF FY 2018 Request Funding for E-Government Initiatives

	FY 2018			Appropriations Account	
Initiative	Agency Contributions	Agency Svc. Fees	NSF Total	AOAM	R&RA
Grants.gov	$263,798	-	$263,798	-	$263,798
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	-	18,938	18,938	14,360	-
USA Jobs	-	10,000	10,000	9,174	-
E-Human Resource Integration	-	24,634	24,634	24,634	-
Integrated Acquisition Environment (IAE)	-	874,354	874,354	21,000	853,354
Human Resources Management LoB	68,478	-	68,478	-	68,478
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	**$606,370**	**$1,797,033**	**$2,403,403**	**$938,275**	**$1,459,724**

PROGRAM ACCOUNTS: R&RA AND EHR $132,090,000

+$11,370,000 / 9.4%

Funding from program accounts Research and Related Activities (R&RA) and Education and Human Resources (EHR) covers approximately 28 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
IPA Costs	**$45.33**	**-**	**$54.32**	**$8.99**	**19.8%**
IPA Compensation	38.33	-	46.11	7.78	20.3%
IPA Lost Consultant & Per Diem	3.92	-	4.59	0.67	17.1%
IPA Travel	3.08	-	3.62	0.54	17.4%
Program Related Administration	**$75.38**	**-**	**$77.77**	**$2.39**	**3.2%**
Program Related Technology	66.28	-	72.72	6.44	9.7%
Other Program Related Administration	9.10	-	5.05	-4.05	-44.5%
Total, R&RA and EHR Funded Organizational Excellence	**$120.72**	**-**	**$132.09**	**$11.37**	**9.4%**

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. IPAs are eligible to receive relocation expenses, or a per diem allowance in lieu of relocation. Reimbursement for income foregone because of their assignment at NSF is allowed only for IPA agreements in place before FY 2017, per NSF's new policy released October 2016. In addition, the new policy is piloting a required 10 percent cost sharing by the IPA's home institution of the IPA's academic-year salary and fringe benefits.

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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Research and Related Activities (R&RA)					
IPA FTE Utilization	146	-	163	17	11.6%
IPA Compensation	$34.71	-	$39.88	$5.17	14.9%
IPA Lost Consultant & Per Diem	3.44	-	3.81	0.37	10.8%
Travel	2.77	-	3.18	0.41	14.6%
Subtotal, R&RA Costs	**$40.93**	**-**	**$46.87**	**$5.94**	**14.5%**
Education and Human Resources (EHR)					
IPA FTE Utilization	29	-	35	6	20.7%
IPA Compensation	$3.62	-	$6.23	$2.61	72.1%
IPA Lost Consultant & Per Diem	0.48	-	0.78	0.30	62.7%
Travel	0.31	-	0.44	0.13	42.3%
Subtotal, EHR Costs	**$4.41**	**-**	**$7.45**	**$3.04**	**69.0%**
Total, IPA FTE Utilization[1]	**183**	**-**	**198**	**15**	**8.2%**
Total, IPA Costs[1]	**$45.33**	**-**	**$54.32**	**$8.99**	**19.8%**

[1] The FY 2016 Actual FTE utilization and total obligations include the costs associated with eight IPA FTE in staff offices (BFA, OIRM, OD, OLPA, and EAC). These eight IPA FTE are not included in this table for FY 2018. Approximately $300,000 in FY 2018 for IPA FTE is budgeted within Other Program Administration and included in the General Program and Evaluation (P&E) activities section of this narrative.

The FY 2018 Request funding for IPA costs is $54.32 million representing an IPA usage level of 199 FTE. FY 2018 R&RA funding for IPAs is $46.87 million supporting 163 IPA FTE. FY 2018 EHR funding for IPAs is 7.45 million supporting 35 IPA FTE. For both R&RA and EHR, per IPA FTE costs are estimated at a level commensurate with the FY 2016 Actual.

FY 2018 total IPA compensation is $46.11 million, lost consultant and per diem is $4.59 million, and travel is $3.62 million. Funding for these three categories is associated with full use of NSF's existing IPA FTE allocation and projected IPA costs for FY 2018.

Program Related Administration

Program Related Administration Investments

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Program Related Technology	$66.28	-	$72.72	$6.44	9.7%
Other Program Related Administration	9.10	-	5.05	-4.05	-44.5%
Total, Program Related Administration	**$75.38**	**-**	**$77.77**	**$2.39**	**3.2%**

The FY 2018 Request for Program Related Administration (PRA) is $77.77 million. 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 2018 increase for PRA is driven by the increased needs and requirements in PRT.

Program Related Technology ($72.72 million)
NSF requests a FY 2018 information technology (IT) investment of $98.0 million. The portion of NSF's IT investment funded through the R&RA and EHR accounts supports NSF's mission activities and accounts for approximately 74 percent of NSF's IT investment portfolio. The remaining $25.28 million IT investment is AOAM funded and is discussed in the AOAM chapter.

Program Related Technology Investments

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual	
				Amount	Percent
Mission-Related Applications and Services	$46.87	-	$47.20	$0.33	0.7%
Mission-Related IT Operations and Infrastructure	14.19	-	19.31	5.11	36.0%
Mission-Related Security and Privacy Services	2.98	-	3.98	1.00	33.4%
Mission-Related IT Management	2.24	-	2.24	-	-
Total, Program Related Technology	**$66.28**	**-**	**$72.72**	**$6.44**	**9.7%**

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 2018, NSF's information technology priorities for PRT are:
- Enhancing the security of NSF's infrastructure to respond to the ever-evolving threat landscape.
- Begin moving towards platform-as-a-service models in alignment with the Federal Government's Cloud First priorities.
- 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 investments that support continuous modernization, including Proposal Management Efficiencies, modernization of the NSF.gov website, and Public Access.
- Expand NSF's Data Management and Delivery (formerly called Enterprise Data Warehouse) to include more data sets and additional reporting tools to strengthen NSF's use of data to drive better decision-making and achieve greater impact.
- Supporting the continued operation of iTRAK, the Foundation's financial management system, and perform database upgrades needed to move to current versions and ensure continued interoperability with NSF's core financial functions.

Mission-Related Applications and Services ($47.20 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. These investments can be classified as:
- Mission Support Systems (formerly Legacy Mission Applications), $35.33 million, supports the following activities:
  - $10.29 million for continuous modernization of systems and services that support the merit review process, such as Proposal Management Efficiencies, Public Access to NSF-funded research, and

  modernization of the content management system for the NSF.gov website. These modernization efforts reduce administrative burden on NSF staff and the research community.
  - $25.04 million provides for the operations and maintenance for NSF's mission support systems, which provide a suite of functionality supporting each stage in the NSF proposal and award management process.
- NSF's Data Management and Delivery investment (formerly Enterprise Data Warehouse), $6.07 million, centralizes and streamlines access to NSF data for NSF staff. The analysis capabilities provided by a modern enterprise data warehouse and related tools inform NSF portfolio management, evaluation, and assessment. The FY 2018 investment will allow NSF to move more NSF data sets into the warehouse and implement additional reporting tools.
- iTRAK is NSF's financial management system. The total FY 2018 investment for iTRAK is $8.29 million. Seventy percent of this request is funded by PRT and 30 percent is funded by AOAM. The PRT portion of the iTRAK request is $5.80 million, to fund operations and maintenance as well as high priority database upgrades, which will ensure the system continues to function efficiently and effectively and the databases remain interoperable with core financial functions.

Mission-Related IT Operations and Infrastructure ($19.31 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 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), which are available 13 hours per day, five days per week.

The FY 2018 Request level will allow for continued modernization of the infrastructure that supports NSF's merit review process as these mission support systems are also modernized. This will enable NSF to take advantage of future opportunities for cloud or shared services as appropriate. Additionally, NSF will begin planning and analysis activities to support movement of its virtualization environment to a platform-as-a-service or offsite hosting model in alignment with the Federal Government's Cloud First priority.

Mission-Related Security and Privacy Services ($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 FY 2018 Request level will be used to support NSF's Continuous Diagnostics and Mitigation (CDM) Program, including CDM training, governance support, and additional human resources needed for implementation and preparing for implementation of CDM Phase 2. Implementation for Phase 2 will begin in the first quarter of FY 2018.

Mission Related IT Management ($2.24 million)
IT Management includes support for the Chief Information Officer and senior IT leadership in the areas of IT strategy and planning, enterprise architecture, capital planning, vendor management, IT budget/finance, and IT strategic communications. This category includes the mission support portion of NSF's IT management services.

<u>Other Program Related Administration</u>
In FY 2018, $5.05 million for NSF's Other PRA includes funding for three Foundation-wide activities:
- 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Proposal Management Efficiencies	$0.31	-	$1.11	$0.80	258.3%
Evaluation and Assessment Capabilities	5.35	-	-	-5.35	-100.0%
E-Government Initiatives	1.01	-	1.46	0.45	45.2%
General Planning and Evaluation Activities	2.43	-	2.48	0.04	1.8%
Total, Other Program Related Administration	**$9.10**	**-**	**$5.05**	**-$4.05**	**-44.5%**

Proposal Management Efficiencies ($1.11 million)
The FY 2018 Budget Request funding for PME will support assessment activities that provide feedback on the impacts of NSF's investments in improving the merit review process and are used to identify further potential enhancements. In addition, support will be provided for a study of the feasibility and impact of double-blind review.

Evaluation and Assessment Capability (zero)
NSF's EAC was established to support, coordinate, and conduct NSF-wide program evaluations and evidence generation and utilization to catalyze learning and improvement through collaboration with NSF's directorates and offices. EAC has become an integral part of NSF's operations and in FY 2018 will transition from an activity in Other PRA to a budget line in Integrative Activities. More detailed information on EAC can be found within the Integrative Activities narrative in the Research and Related Activities chapter.

E-Government Initiatives ($1.46 million)
The FY 2018 Budget Request for NSF program-supported and mission-related E-Government initiatives is consistent with the FY 2018 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 increasing NSF's service fee for IAE-loans and grants approximately $618,000;
- NSF's contribution to the Budget Formulation and Execution Line of Business increases $5,000;
- NSF's contribution to the Human Resource Management Line of Business increases approximately $3,000; and
- Grants.gov changed its agency charging algorithm decreasing NSF's service fee by approximately $172,000.

General Planning and Evaluation Activities ($2.48 million)
FY 2018 funding for general planning and evaluation activities supports investments on broad programmatic and policy matters of NSF-wide scope and benefit. This includes activities such as the verification and validation of performance information; IPA FTE in the office of Budget Finance and Award Management; and certain costs associated with the American Association for the Advancement of Science (AAAS) fellowships program. The FY 2018 funding estimate is based on the level of general planning and evaluation activities and projects that occurred in FY 2016 and anticipated activities for FY 2018.

AGENCY OPERATIONS AND AWARD MANAGEMENT

$328,510,000
-$22,600,000 / -6.4%

Summary of Agency Operations and Award Management

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Personnel Compensation and Benefits[1]	$208.93	-	$226.00	$17.07	8.2%
Management of Human Capital	10.09	-	10.11	0.01	0.1%
Travel	5.75	-	5.45	-0.30	-5.2%
Information Technology	21.94	-	25.28	3.34	15.2%
Space Rental	33.37	-	27.75	-5.62	-16.8%
Operating Expenses	17.35	-	19.83	2.47	14.2%
Building and Administrative Services	13.81	-	13.10	-0.71	-5.1%
NSF HQ Relocation	39.87	-	1.00	-38.87	-97.5%
Total, AOAM	**$351.11**	**-**	**$328.51**	**-$22.60**	**-6.4%**

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2016, $5.48 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $214.41 million. Approximately $5.82 million in ACRs are expected in FY 2018 to meet the total PC&B requirement of $231.81 million.

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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual 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	1,276	-	1,310	34	2.7%
NSF AOAM -- Pathways Intern	34	-	42	8	23.5%
Subtotal, FTE Usage	**1,310**	**-**	**1,352**	**42**	**3.2%**
Detailees to NSF	3	-	3	-	-
Total, Workforce (Usage)	**1,313**	**-**	**1,355**	**42**	**3.2%**

NSF's FY 2018 FTE allocation of 1,352 represents no change from the FY 2016 Actual. The FY 2018 FTE estimated usage is 1,310 regular and 42 Pathways FTE.

Personnel Compensation and Benefits (PC&B)

Personnel Compensation & Benefits
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
Regular FTE Usage (projected)	1,276	-	1,310	34	2.7%
Student FTE Usage (projected)	34	-	42	*8*	*23.5%*
Regular FTE Base Salary	$160.84	-	$171.90	$11.05	6.9%
Student Salary	1.39	-	$1.75	0.36	25.9%
Other Compensation[1]	1.12	-	$1.55	0.43	38.8%
Awards	2.01	-	$2.09	0.08	4.1%
Subtotal, FTE Compensation	**$165.35**	**-**	**$177.28**	**$11.93**	**7.2%**
Benefits	47.25	-	$49.45	2.21	4.7%
Other Benefits[2]	1.81	-	$1.91	0.11	5.9%
Subtotal, Benefits	**$49.05**	**-**	**$51.37**	**$2.31**	**4.7%**
COLA[3]	-	-	$3.17	3.17	N/A
Total, PC&B	**$214.41**	**-**	**$231.81**	**$17.41**	**8.1%**
Source of Funds:					
AOAM Appropriaton	208.93	-	$226.00	17.07	8.2%
Administrative Cost Recoveries[4]	5.48	-	$5.82	0.34	6.1%
Total, Resources for PC&B	**$214.41**	**-**	**$231.81**	**$17.41**	**8.1%**

[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 2018: includes nine months of the projected pay raise of 1.9 percent; it increases FTE Compensation costs by $2.46 million and Benefits by $702,000.

[4] ACR levels for FY 2018 are estimated based on the levels in FY 2014.

The total FY 2018 Request amount for Personnel Compensation and Benefits is $231.81 million. Funding for PC&B reflects funding from two sources: $226.0 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 2018 year-end usage of 1,310 regular full-time equivalent (FTE) employees, a total of 42 Pathways intern FTE, a projected FY 2018 pay raise of 1.9 percent, associated cost of benefits, general workforce performance awards (GWFPA), and Senior Executive Service (SES) bonuses. The FY 2018 Request for PC&B also contains $917,000 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

Management of Human Capital
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$10.09	-	$10.11	$0.01	0.1%

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. The $10.17 million in the FY 2018 Request will support:

- $3.28 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. Support for these activities, including the adjudications of personnel security and suitability investigations, will help ensure a smooth transition of the workforce to NSF's new headquarters in anticipation of increased staff turnover associated with the move.
- $1.43 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), and eRecruit capabilities using USAJobs, and providing support for personnel security and suitability investigations for incoming staff.
- $1.82 million for strategic human capital support contracts. 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.
- $2.51 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. FY 2018 funding will support training and development activities designed to help ensure that the workforce is equipped with the tools needed to settle into the new headquarters with minimal impact on mission accomplishment.
- $150,000 for other program support including outreach and licenses for key on-line reference materials.
- $915,000 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 FY 2018 funding level for Management of Human Capital will result in limited 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

NSF Employee FTE Travel

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$5.75	-	$5.45	-$0.30	-5.2%

The FY 2018 Request amount of $5.45 million for NSF employee FTE travel is based on the travel activity associated with utilization of 1,310 regular FTE. It includes travel-related funding for site reviews, outreach activities, and post-award monitoring and oversight related to the projected level of program activities contained in the FY 2018 Request.

Information Technology

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; security and privacy services; and related IT management services funded by the AOAM account are discussed below.

AOAM Information Technology

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Administrative Applications Services and Support	$5.41	-	$7.51	$2.10	38.8%
Administrative IT Operations and Infrastructure	12.99	-	14.23	1.24	9.6%
Administrative Security and Privacy Services	3.03	-	3.03	-	-
Administrative IT Management	0.51	-	0.51	-	-
Total, AOAM IT	**$21.94**	**-**	**$25.28**	**$3.34**	**15.2%**

Information technology investments 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 2018, NSF's information technology priorities for AOAM include:

- Completing the move to the new NSF headquarters in Alexandria and decommissioning the old NSF building in Arlington.
- Supporting NSF staff through increased help desk and infrastructure support as they begin using IT services in the new Alexandria headquarters.

- Enhancing the security of NSF's infrastructure to respond to the ever-evolving threat landscape in support of the Cybersecurity Cross-Agency Priority goal: Provide ongoing observation, assessment, analysis, and diagnosis of an organization's cybersecurity: posture, hygiene, and operational readiness.
- Supporting the continued operation of iTRAK, the Foundation's financial management system and database upgrades needed to move to current versions to ensure continued interoperability with NSF's core financial functions.
- Supporting the new financial services support investment, distinct from the iTRAK investment which supports core financials, to provide end-to-end electronic support for the full suite of NSF's financial management functions.
- Making high priority changes to support the efficiency and effectiveness of NSF's administrative applications services, including NSF collaboration sites (SharePoint).

<u>Administrative Applications Services and Support ($7.51 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 2018, the total request for iTRAK is $8.29 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 $2.49 million and will fund high priority database upgrades, which will ensure the system continues to function efficiently and effectively and the databases remain interoperable with core financial functions.
- A total of $900,000 will be used to support a new financial services support investment, distinct from the iTRAK core financials investment, to provide end-to-end electronic support for the full suite of NSF's financial management functions. The funding will be used to support planning, selection, and initial development of the first component of this investment, which includes modernization of both administrative and merit review financial services.
- Other administrative applications services funding, $2.97 million, will provide for high priority changes to NSF's collaboration tools, such as upgrading to the current version of SharePoint to ensure sustained operation of collaboration sites and their continued interoperability with NSF's desktop services.
- A total of $1.16 million 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 ($14.23 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 increase requested for FY 2018 will support the completion of the move to the new headquarters in Alexandria and decommissioning the old NSF building in Arlington. Additionally, it will provide increased help desk and infrastructure support to troubleshoot issues and help staff with IT set-up as they begin settling in to their new offices and using IT services in the new building.

Administrative Security and Privacy Services ($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, continuous diagnostics and mitigation (CDM) program, application security, security control testing and tools, automated vulnerability assessment tools, and remediation and intrusion detection services related to administrative applications.

Administrative IT Management ($510,000)
IT Management includes support for the Chief Information Officer and senior IT leadership in the areas of IT strategy and planning, enterprise architecture, capital planning, vendor management, IT budget/finance, and IT strategic communications. This category includes the administrative services portion of NSF's IT management services.

Space Rental

Space Rental
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$33.37	-	$27.75	-$5.62	-16.8%

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. In addition, rent paid for the parking structure to the owner of the new headquarters building in Alexandria is included.

The FY 2018 Request for Space Rental is $27.75 million. NSF currently occupies two adjoining, leased office buildings located in Arlington, Virginia. The current leases for both buildings have been replaced by interim occupancy agreements that extend occupancy until the move to the new headquarters in the fourth quarter of FY 2017. The interim occupancy agreements were negotiated by GSA with the current landlord and reflect current market rates for the Arlington area. Beginning in FY 2018, NSF will occupy over 700,000 square feet of space, primarily in one leased office building located in Alexandria, Virginia.

The decrease of $5.62 million in FY 2018 reflects savings realized through release of the Stafford I and Stafford II buildings in Arlington by FY 2018 and additional savings 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

Operating Expenses
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$17.35	-	$19.83	$2.47	14.2%

The FY 2018 Request for Operating Expenses is $19.83 million. 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 2018 Request are described below.

- A total of $10.21 million 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 2018.
- $4.02 million supports post-award monitoring and oversight advanced monitoring reviews; NSF's annual risk assessment, large facility business systems reviews, contract close-out, and NSF outreach activities and materials.
- $1.75 million provides financial management support, including financial statement reporting, NSF property reporting, audit deficiencies resolution assistance, and reporting associated with the financial system.
- $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 FY 2018 funding will support a risk assessment requirement to ensure compliance with improper payment regulations.
- $381,000 supports the 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. FY 2018 funding ensures that the system and related data analysis will continue to respond to evolving information needs.
- $181,000 provides dedicated, on-site, project management support to plan, coordinate, and execute NSF's implementation of the Digital Accountability and Transparency Act (DATA Act).
- $347,000 maintains on-going licensing, subscription, and infrastructure support for the Automated Acquisition Management System(AAMS) —NSF's E-procurement system.
- $328,000 provides support for the review of grantee expenditures for improper payments as per the Improper Payments Elimination and Reduction Act (IPERA), NSF's grant accrual, and Award Cash Management Service (ACM$) 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.
- $319,000 to provide contractor support for the Annual Large Facilities Workshop to include conference center space, lodging, guest speakers, and other related logistical and planning support; an interagency agreement that supplements NSF efforts in meeting a federal mandate to negotiate indirect cost rates for awardees over which NSF has cognizance; interagency agreements for Fair Pay and Safe Work and Integrated Acquisition Environment; services for printing 1099's; Acuity's routing number file for financial institution payment information.
- A total of $250,000 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 $220,000 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.
- $184,000 supports administrative grants processing duties including, processing funding actions, reviewing payment requests, and answering inquiries. In addition, this includes verifying Davis-Bacon Act reports.
- $90,000 provides contract support and purchase card program review and transaction support.
- $25,000 will provide support for increased cost analysis responsibilities due to the implementation of Standardized Cost Analysis Guidance, which became effective June 2014. The funding for the audits conducted under this contract will largely be sourced from MREFC funding for large facility construction cooperative agreements and R&RA funding for large facility operations cooperative

agreements. The $25,000 in AOAM funding requested is for special projects not specific to an awardee (for example, support in revising and improving the Large Facilities Financial Data Collection Tool, which is an audit readiness tool and a new requirement for Large Facility Awardees to complete).

Building and Administrative Services

Building and Administrative Services
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual	
				Amount	Percent
Information Dissemination	$3.42	-	$2.41	-$1.01	-29.6%
Workplace Management	5.31	-	5.27	-0.03	-0.7%
Panel Support, Meeting Management, and Proposal Services	5.08	-	5.42	0.34	6.6%
Total, Building & Administrative Services	**$13.81**	**-**	**$13.10**	**-$0.71**	**-5.1%**

The FY 2018 Request of $13.10 million associated with Building and Administrative Services will support three sets of activities: information dissemination; workplace management; and panel support, meeting management, and proposal services.

<u>Information Dissemination ($2.41 million)</u>
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 is realized through the cost savings provided by these modernization efforts.

<u>Workplace Management ($5.27 million)</u>
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.

<u>Panel Support, Meeting Management, and Proposal Services ($5.42 million)</u>
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.

The $340,000 increase in FY 2018 will be applied to two activities with an offset in the elimination of the Proposal Processing Unit:

- Support for the anticipated workload increase for audio-visual management in the larger panel center at the new Alexandria headquarters. DAS provides conference room and event management support including reservation software and booking assistance, logistical, audio-visual and Unified Communications tool support for grant panels and directorate/division specific meetings.
- Support to migrate all current network and non-network printing devices to multi-function devices thereby eliminating expensive/aged, single function and/or single user devices, improving efficiency, cyber security, and environmental sustainability while reducing overall costs and streamlining the maintenance and operations of the NSF's printing infrastructure.
- The elimination of central print processing of proposals will result in significant savings, and promote efficient business practices in accordance with Executive Order 13589—Promoting Efficient Spending. Directorates requiring a printed proposal copy would still have an option to print single copies to their local multi-function devices.

NSF Headquarters Relocation

NSF Headquarters Relocation

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$39.87	-	$1.00	-$38.87	-97.5%

NSF is anticipated to complete the move of its headquarters to the new building in Alexandria, VA by October 1, 2017. A budget in FY 2018 remains for items such as decommissioning of the current headquarters buildings and unanticipated changes required at the new headquarters.

Previous NSF funding was required to manage the relocation 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.

AOAM by Object Class

AOAM by Object Class

(Dollars in Thousands)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request[1]	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Personnel Compensation	$159,872	-	$173,927	$14,055	8.8%
Personnel Benefits	48,812	-	52,072	3,260	6.7%
Travel and Transportation of Persons	5,767	-	5,450	-317	-5.5%
Transportation of Things	627	-	630	3	0.5%
Rental Payments to GSA	33,370	-	26,980	-6,390	-19.1%
Rent to Others	87	-	860	773	888.5%
Communications, Utilities and Misc. Charges	2,579	-	2,621	42	1.6%
Printing and Reproduction	179	-	183	4	2.2%
Advisory and Assistance Services	78,155	-	43,506	-34,649	-44.3%
Other Services	7,035	-	7,560	525	7.5%
Purchases of Goods & Srvcs from Gov't. Accts	7,480	-	7,400	-80	-1.1%
Operations and Maintenance of Facilities	7	-	8	1	14.3%
Operations and Maintenance of Equipment	48	-	52	4	8.3%
Supplies and Materials	1,151	-	1,175	24	2.1%
Equipment	5,941	-	6,086	145	2.4%
Land and Structures	-	-	-	-	N/A
Total, AOAM	**$351,110**	**-**	**$328,510**	**-$22,600**	**-6.4%**

[1] This table reflects recent updates and may not match what is shown in the President's Budget Appendix.

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.

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 Alexandria, Virginia.

Rental Payments to Others: This category includes rent paid for the parking structure to the owner of the new headquarters building in 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; and support for OMB Circular A-123 reviews.

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).

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.

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:~~*$328,510,000*: *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~~*2018* 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~~*$5,000,000* shall remain available until expended.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Agency Operations and Award Management
FY 2018 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 2016 Appropriation	$330.00	18.11	-$23.71	-$0.29	$27.00	$351.11
FY 2017 Annualized CR	329.37	23.71				353.08
FY 2018 Request	328.51					328.51
$ Change from FY 2017 Annualized CR						-$24.57
% Change from FY 2017 Annualized CR						-7.0%

Explanation of Carryover

Within the **Agency Operations and Award Management** (AOAM) no-year component, $23.71 million was carried over into FY 2017.

NSF Headquarters Relocation
- Amount: $23.71 million
- Reason: Obligations planned for FY 2016 were shifted to FY 2017.
- Anticipated Obligation: FY 2017 Quarter 3

NATIONAL SCIENCE BOARD (NSB) $4,370,000
+$60,000 / 1.4%

The FY 2018 Budget Request for the National Science Board (NSB, Board) is $4.37 million, an increase of $60,000 from the FY 2016 Actual of $4.31 million. The FY 2018 Budget Request will enable the Board to fulfill its policymaking and oversight responsibilities for NSF. It will also allow the Board to continue its statutory responsibilities, including activities related to the review of major research facilities projects.

National Science Board Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total, NSB	**$4.31**	**$4.36**	**$4.37**	**$0.06**	**1.4%**
Full-Time Equivalents (FTEs)	18	19	19	1	5.3%

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: *Provided*, That not to exceed $2,500 shall be available for official reception and representation expenses.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

National Science Board
FY 2018 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Expired	Obligations Actual/ Estimates
FY 2016 Appropriation	$4.37	-$0.06	$4.31
FY 2017 Annualized CR	4.36		4.36
FY 2018 Request	4.37		4.37
$ Change from FY 2017 Annualized CR			$0.01
% Change from FY 2017 Annualized CR			0.2%

National Science Board in Context
The NSB, established by the NSF Act of 1950, has dual responsibilities to: provide national science policy advice to the President and Congress; and establish policies for NSF within the framework of applicable national policies as set forth by the President and the Congress. 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 Nation. Board members serve six-year terms on staggered appointments and are drawn from industry, academe, non-profit organizations, government, and professional scientific

societies representing the breadth of S&E disciplines. They are selected to represent all areas of the Nation based on their eminence in research, education, or public service.

The Board currently convenes four formally scheduled public meetings per year, with additional meetings as needed, to review and approve major NSF awards; provide guidance on new programs; oversee and provide policy direction to NSF; and address 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 S&E research, 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 community and NSF management. Recent reports have examined topics such as higher education as a public and private good and the Science, Technology, Engineering, and Mathematics (STEM) workforce.

The Board has several standing committees to assist with its responsibilities. To enable the Board to fulfill its statutory and governance roles more effectively, the Board approved these new committees and charges in February 2017:

Executive Committee – This statutory Committee includes the Director of NSF, who chairs the Committee, and four elected members from the Board. The Board has delegated to this Committee its authority to approve awards in the rare instances when immediate action is required between Board meetings.

Committee on Oversight – Conducts independent oversight of NSF's operations, processes for risk management, audit plans and results, and processes for complying with laws and regulations; reviews Office of the Inspector General activities and NSF management responses; monitors audits and makes related recommendations to the Board; and oversees the Board's compliance with the Sunshine Act.

Committee on Strategy – Provides a forum for developing the Board's strategic discussions of NSF's budget, programs, organization structure and agency vision; makes recommendations to the Board on annual Budget Requests and quadrennial Strategic Plans; and provides strategic guidance to the Board on NSF's programs.

Committee on National S&E Policy – Oversees development and production of the congressionally-mandated *Science and Engineering Indicators (Indicators)* report in collaboration with NSF's National Center for Science and Engineering Statistics; helps ensure that the S&E information and policy resources developed by the NSB are high-quality, policy-relevant, and accessible in order to meet stakeholder needs; and helps fulfill the NSB's charge to provide ongoing information and policy advice to Congress and the President on S&E research, education, and workforce issues.

Committee on Awards and Facilities – Addresses strategic issues and recommends policies to the Board related to awards and Major Research Equipment and Facilities Construction projects; makes recommendations to the Board on awards and facilities; and provides lifecycle oversight on facilities and oversight on awards.

Committee on External Engagement – Leads the NSB's communication and engagement efforts with government, industry, the public and the research and education communities, and helps the Board advance the pursuit of national policies for the promotion of research and education in science and engineering.

Subcommittee on Honorary Awards – Reviews nominations for two awards established by the Board: the Vannevar Bush Award and the Public Service Award.

Office of the National Science Board
Personnel Compensation and Benefits and Other Operating Expenses
(Dollars in Thousands)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Personnel Compensation Benefits (PC&B)[1]	$3,042	-	$3,141	$99	3.3%
Staff Development and Training	40	-	38	-2	-5.0%
Advisory and Assistance Services	792	-	740	-52	-6.6%
Travel and Transportation of Persons	217	-	308	91	41.9%
Communications, Supplies, and Equipment	212	-	140	-72	-34.0%
Representation Costs	2	-	3	1	50.0%
Total, NSB	**$4,305**	**$4,360**	**$4,370**	**$65**	**1.5%**
Full-Time Equivalent	18	-	19	1	5.6%

[1] FY 2018 PC&B includes a pay raise of 1.9 percent, as well as anticipated within grade and promotion increases.

Personnel Compensation and Benefits

The Board's FY 2018 budget supports a core of full-time policy, communications, administrative, legal, and executive secretariat staff. In addition to providing institutional memory for the Board, the Board Office staff provides both the resources and expertise for coordinating and conducting science and education policy analyses and development and implementing broad communication and outreach programs. Staff also advise the Board on legal aspects of its policies and activities and provides 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 support from organizations such as the Science and Technology Policy Institute, a federally funded research and development center supported by NSF. The next edition of *Indicators* is scheduled for delivery to Congress in January 2018.

Another item in the Advisory and Assistance Services line is the maintenance of a 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. 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.

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 of equipment such as copiers and computers.

The FY 2018 Budget Request will facilitate the continued thoughtful enhancement of the Board's efforts to strengthen the U.S. science and engineering enterprise through its policy and information-related activities. Specifically, the Request will support the NSB's continued engagement with stakeholders—including Congress, the Administration, academia, the business community, and the general public—to better understand their diverse needs. In turn, this will help the NSB (and National Center for Science and Engineering Statistics) improve the usefulness of the resources it produces, ensuring that these stakeholders continue to have access to timely, comprehensible, and objective S&E data and policy guidance.

OFFICE OF INSPECTOR GENERAL (OIG) $15,008,000

+$248,000 / 1.7%

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 2018 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 2018 Budget Request for OIG is $15.01 million, an increase of $248,000 from the FY 2016 Actual of $14.76 million.

Office of Inspector General Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Total, OIG	**$14.76**	**$15.13**	**$15.01**	**$0.25**	**1.7%**
Full-Time Equivalents (FTEs)	67	72	69	2	2.8%

Appropriations Language

For necessary expenses of the Office of Inspector General as authorized by the Inspector General Act of 1978, ~~$15,160,000,~~*$15,008,000*, of which $400,000 shall remain available until September 30, ~~2017.~~*2019*.

(Note – A full-year 2017 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Further Continuing Appropriations Act, 2017 (P.L. 114-254). The amounts included for 2017 reflect the annualized level provided by the continuing resolution.)

Office of Inspector General

FY 2018 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 2016 Appropriation	$15.16	$0.17	-$0.38	-$0.19	$14.76
FY 2017 Annualized CR	15.13	0.38			15.51
FY 2018 Request	15.01				15.01
$ Change from FY 2017 Annualized CR					-$0.50
% Change from FY 2017 Annualized CR					-3.2%

Explanation of Carryover

Within the **Office of Inspector General (OIG)** two-year account, $380,002 was carried over into FY 2017.

Office of the Inspector General

- Amount: $380,002
- 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 2017 Quarter 4

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; and 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 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. Audit work mandated by the Federal Information Security Modernization Act of 2014 (FISMA), the Improper Payments Elimination and Recovery Act (IPERA), and the Digital Accountability and Transparency Act (DATA Act) is also performed annually.

OIG also audits the 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. OIG 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, the 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 audit of the agency's financial statements and annual review of its compliance with the Federal Information Security Modernization Act of 2014 (FISMA).

Office of Inspector General
Personnel Compensation and Benefits and General Operating Expenses
(Dollars in Thousands)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
Personnel Compensation and Benefits[1]	$11,476	-	$12,075	$599	5.2%
Travel & Transportation of Persons	186	-	180	-6	-3.2%
Advisory & Assistance Services[2]	2,655	-	2,283	-372	-14.0%
Rent	76	-	95	19	25.0%
Information Technology	90	-	50	-40	-44.4%
Communications, Supplies, Equipment & Other Services	279	-	325	46	16.5%
Training	*140*	-	*175*	*35*	*25.0%*
Other	*139*	-	*150*	*11*	*7.9%*
Total, OIG	**$14,762**	**$15,130**	**$15,008**	**$246**	**1.7%**
Full-Time Equivalents	67		69	2	3.0%

[1] Includes projected 2018 pay raise of 1.9 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 2018 appropriation of $15.01 million will enable OIG to carry out the core elements of its mission and maintain a workforce of 69 FTEs. NSF's portfolio of grants and cooperative agreements increases in complexity each year, and requires the majority of OIG's audit and investigative resources. However, we project that rising personnel and contract costs will limit spending on audit contracts, training, technology, and preventive activities.

At the beginning of FY 2017, five professional staff were added to program areas where workload imbalances are of greatest concern. As our current workforce ages, new hires are critical to revitalizing our workforce and are carefully vetted not just for technical skills but also for their readiness to assume future management responsibilities. Currently, approximately 24 percent of our staff (mostly managers) are eligible to retire.

Between FY 2013 and FY 2016, OIG has sustained an increase in its average cost per FTE of about 18 percent, as personnel costs and benefits have increased, and professionals such as lawyers, investigators and CPAs replace administrative staff. 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. 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 be curtailed to fund more urgent programmatic priorities.

Office of Audits (OA). The Office of Audit conducts audits and reviews of NSF's finances and operations that are either mandated by statute or discretionary. Audit work required by statute has grown in recent years from auditing NSF's financial statements and compliance with the Federal Information Security Modernization Act of 2014 (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 than had previously been the case. In FY 2017, we estimate that the cost of the Financial Statements and FISMA contract will amount to approximately $1.10 million, up from $940,000 in FY 2015.

The increased costs for the OIG's mandatory work has reduced the capacity of OA to perform discretionary audits, which target high-risk programs and institutions. The universe of potential discretionary audits is large, consisting of about 42,000 active awards worth $28.0 billion. Historically, the OA audit plan includes about 40 discretionary audits.

Much of our discretionary audit work recently has focused on NSF's construction and management of its large facilities. Since 2010, OIG has issued 28 reports containing more than 80 recommendations to improve NSF's use and management of cooperative agreements for the construction and operation of its high-dollar, high-risk research facilities. NSF has adopted new policies and procedures to strengthen its monitoring of large facilities as a direct result of these reports. NSF frequently funds the development of large-scale, multiuser scientific facilities through federal assistance awards under cooperative agreements (CAs). As of February 2016, NSF supports a broad array of 28 major research facilities, which individually cost between $100.0 million and $500.0 million each to construct. As of January 2017, NSF had 459 active cooperative agreements totaling nearly $8.0 billion.

Twenty-two of these agreements are valued at over $50.0 million each and add up cumulatively to more than $4.40 billion. Recent OIG audits and reviews of NSF's oversight of four of these facilities identified several control issues which the Foundation has begun to address. This initiative will help strengthen the Foundation's ability to ensure grant and procurement funds are not wasted by improper expenditures and mismanagement. Strong controls, as well as increased oversight by additional OIG staff, will help ensure NSF obtains critical assets and services necessary to meet its missions in a declining budget environment.

For example, construction is ongoing for the $469.0 million National Ecological Observatory Network (NEON), a continental-scale observation system for examining ecological change over time. 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 $154.0 million in questioned and unsupported costs (approximately 36 percent of the total budget). Our concerns about NEON's finances were validated in June 2015 when NEON management informed NSF that the project was facing a potential cost overrun of $80.0 million. Similar issues surfaced during OIG's review of proposed costs for the $467.70 million Large Synoptic Survey Telescope (LSST).

In a given year, NSF spends significantly more on operating its facilities than it does on constructing them. NSF requested over $193.0 million for fiscal year 2017 to pay for four large facility construction projects. In contrast, NSF's operation and maintenance request for its existing large facilities for the same time period was over $1.0 billion. We have recently initiated a review focusing on the risk of commingling construction and operations funds. Ensuring that strong controls exist over the use of such funds is vital, as use of operations funds for construction work can hide cost overruns and deplete funding needed for the operations phase. OIG will also monitor the actions NSF takes in response to requirements in the American Innovation and Competitiveness Act, which mandates a number of important controls to be applied in the development of NSF's large facilities projects.

OIG audits have also led NSF to pay more attention to the amounts it pays scientists, engineers, and educators who come to NSF under Intergovernmental Personnel Act (IPA) assignments. Individuals on IPA appointments remain employees of their home institutions. As a result, pay and benefits for IPAs are set by their home institutions and are not subject to limitations on federal pay and benefits.

Audits issued in 2013 and 2016 found that the Foundation's use of IPAs comes at increasing cost. In 2015, NSF paid nearly $8.90 million for 27 executive-level IPAs, compared to $6.50 million for 21 executive level IPAs in 2012. IPA salaries can also significantly exceed the salaries of the highest paid federal employees. In 2015 the highest executive-level IPA salary was more than $440,000, up 45 percent from $301,247 in 2012. In 2015, the salaries for all but two executive level IPAs were more than the highest salary of any federal employee at NSF. Our audits recommended that NSF evaluate ways to reduce IPA costs and NSF has begun to take action.

Office of Investigations (OI). OI investigations cover the entire spectrum of investigative functions, and is comprised of three units. The Research Integrity/Admin Investigations (RIA) division is primarily responsible for investigating allegations of Research Misconduct (RM) and personnel misconduct within NSF. Our Program Integrity (PI) division is primarily responsible for investigating allegations of civil and criminal wrongdoing. The Investigative Legal (IL) division works with both RIA and PI in the successful accomplishment of investigations, liaison activities, and outreach to both the government and science communities.

The work of OIG's Office of Investigations (OI) serves as an important deterrent to grant fraud and research misconduct and consistently contributes much more than its cost to the government's bottom line. Between FY 2009 and FY 2016, OI recovered almost $35.0 million for the government. In FY 2016 alone, our 21 staff investigators recovered $8,926,748, an average of $425,083 per investigator, approximately three times their average salaries.

OI's workload has increased in recent years due primarily to growth in Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) cases. In particular, OIG has successfully partnered with NSF program managers to improve the identification of the nature and extent of fraudulent conduct on the part of grant recipients under the SBIR/STTR program. Our proactive efforts generated over 175 SBIR/STTR-related cases, while the number of awards has increased from 599 to 715 (an increase of almost 20 percent) over three years.

Despite its relatively small size, OI's activities consistently benefit agencies beyond NSF. Among other things, its staff has produced and annually updates a digest of successfully prosecuted grant fraud cases. This has been used by civil and criminal Assistant United States Attorneys across the country to facilitate prosecutions of individuals who have defrauded grant-funding agencies and/or the SBIR/STTR set aside programs.

In FY 2016, OI hosted its fifth Suspension and Debarment (S&D) Workshop. These free events (which are now co-sponsored by the Interagency Suspension and Debarment Council) have trained hundreds of individuals from OIGs, Suspension and Debarment Offices, Offices of General Counsel and United States Attorney's Offices. As a result of these workshops, several agencies that were not previously using suspensions or debarments to protect federal funds have begun to do so, and agencies that were using these critical tools have strengthened their practices and identified more robust ways to protect federal funds.

Also in FY 2016, OI sponsored its second SBIR workshop. Like the S&D workshops, this free event helped investigators, DOJ attorneys, and program personnel identify new and improved ways to fight fraud in the SBIR program. As a result of these workshops and OI's leadership role in this area, many agencies (including the Department of Health and Human Services OIG and the Air Force) have created new programs to fight fraud in the SBIR program or enhanced existing ones.

OIG Support Functions. Most office-wide support functions fall under the executive leadership of an Assistant Inspector General (who also serves as OIG's Legal Counsel) and are functionally encompassed within two operating units—an immediate office and a management division.

Immediate office functions comprise those 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, such as increasing the use and effectiveness of suspension and debarment remedies to protect taxpayer funds.

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 help OIG staff recognize and deal with legal concerns as early as possible.

OIG's management/administrative arm 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 across the OIG have been streamlined to the maximum extent practical.

Information Technology. Spending on hardware, software, and IT services is expected to remain at a reduced level through FY 2018. OIG plans to reduce its costs for computers and printers by lengthening their replacement cycle, phasing out the use of desktop printers and relying more on network printers.

Preventive initiatives. To optimize limited budget resources OIG has already reduced 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 grant fraud, research misconduct, and 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. 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.

MAJOR MULTI-USER RESEARCH FACILITIES

Major Multi-User Research Facilities Funding

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Total Research and Related Activities	**$1,009.79**	**-**	**$963.50**	**-$46.29**	**-4.6%**
Operations and Maintenance of Existing Facilities	727.14	-	676.94	-50.20	-6.9%
Federally Funded Research and Development Centers	218.59	-	203.76	-14.83	-6.8%
Operations and Maintenance of Facilities under Construction	46.47	-	81.00	34.53	74.3%
R&RA Planning and Concept Development	17.59	-	1.80	-15.79	-89.8%
Major Research Equipment and Facilities Construction	**$241.48**	**-**	**$182.80**	**-$58.68**	**-24.3%**
Total, Major Multi-User Research Facilities	**$1,251.27**	**-**	**$1,146.30**	**-$104.97**	**-8.4%**

NSF investments provide state-of-the-art tools for research and education. These include major multi-user research facilities such as instrumentation networks, 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 major multi-user facilities are funded through the Research and Related Activities (R&RA) account, with most construction 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 major 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
Operations and Maintenance of Existing Facilities	**$727.14**	**-**	**$676.94**	**-$50.20**	**-6.9%**
Engineering					
National Nanotechnology Coordinated Infrastructure (NNCI)	16.33	-	14.78	-1.55	-9.5%
Natural Hazards Engineering Research Infrastructure (NHERI)	13.00	-	11.75	-1.25	-9.6%
Geosciences					
Academic Research Fleet[1]	82.79	-	77.80	-4.99	-6.0%
Geodesy Advancing Geosciences and EarthScope (GAGE)	13.18	-	12.22	-0.96	-7.3%
International Ocean Discovery Program (IODP)	48.00	-	48.00	-	-
Ocean Observatories Initiative (OOI)	54.98	-	31.00	-23.98	-43.6%
Polar Facilities and Logistics	293.82	-	283.16	-10.66	-3.6%
Seismological Facilities for the Advancement of Geoscience & EarthScope (SAGE)	25.64	-	24.19	-1.45	-5.7%
Mathematical and Physical Sciences					
Arecibo Observatory	8.90	-	7.72	-1.18	-13.3%
Cornell High Energy Synchrotron Source (CHESS)[3]	20.03	-	16.00	-4.03	-20.1%
Gemini Observatory	19.88	-	21.03	1.15	5.8%
IceCube Neutrino Observatory	8.71	-	7.00	-1.71	-19.6%
Large Hadron Collider (LHC)[2]	20.00	-	22.30	2.30	11.5%
Laser Interferometer Gravitational Wave Observatory (LIGO)	39.43	-	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)	35.34	-	34.77	-0.57	-1.6%
National Superconducting Cyclotron Laboratory (NSCL)	24.00	-	23.00	-1.00	-4.2%
Other Facilities[3]	3.10	-	2.79	-0.31	-10.0%
Federally Funded Research and Development Centers[4]	**$218.59**	**-**	**$203.76**	**-$14.83**	**-6.8%**
National Center for Atmospheric Research (NCAR)	105.60	-	89.90	-15.70	-14.9%
National Optical Astronomy Observatory (NOAO)	21.99	-	20.67	-1.32	-6.0%
National Radio Astronomy Observatory (NRAO)[5]	81.50	-	76.34	-5.16	-6.3%
Other Astronomical Facilities[6]	-	-	11.85	11.85	N/A
National Solar Observatory (NSO)[7]	9.50	-	5.00	-4.50	-47.4%
Operations and Maintenance of Facilities under Construction	**$46.47**	**-**	**$81.00**	**$34.53**	**74.3%**
Daniel K. Inouye Solar Telescope (DKIST)[8]	13.50	-	16.00	2.50	18.5%
National Ecological Observatory Network (NEON)	32.97	-	65.00	32.03	97.1%
R&RA Planning and Concept Development	**$17.59**	**-**	**$1.80**	**-$15.79**	**-89.8%**
Pre-construction Planning[9]	17.59	-	1.80	-15.79	-89.8%
Major Research Equipment and Facilities Construction[10]	**$241.48**	**-**	**$182.80**	**-$58.68**	**-24.3%**
Total, Major Multi-User Research Facilities	**$1,251.27**	**-**	**$1,146.30**	**-$104.97**	**-8.4%**

[1] 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.

[2] Large Hadron Collider (LHC) funding on this line includes $6.30 million in FY 2018 for planning for a potential LHC upgrade.

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

[4] 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.

[5] 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 shown 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.

[6] Other Astronomical Facilities funding includes the Green Bank Observatory and the Very Long Baseline Array, removed from NRAO and ALMA.

[7] National Solar Observatory (NSO) totals presented do not include $11.50 million in FY 2016, and $14.0 million in FY 2018 for operations and maintenance support for the DKIST facility construction project. That funding is captured within the total presented Initial Operations and Maintenance During Construction line.

[8] Of total DKIST funding presented, $11.50 million in FY 2016 and $14.0 million in FY 2018 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.

[9] Pre-construction planning includes funding for potential next generation multi-user facilities. This line reflects funding for Antarctic Infrastructure Modernization for Science (AIMS) for FY 2016 and FY 2018 and for Regional Class Research Vessels (RCRV) for FY 2016 only. RCRV funding is $3.09 million in FY 2016. AIMS funding is $14.50 million in FY 2016, and $1.80 million in FY 2018.

[10] 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.

NSF Facilities Investments in FY 2018

The following pages contain information on NSF's ongoing facilities in FY 2018.

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ACADEMIC RESEARCH FLEET $77,800,000 -$8,080,000 / -9.4%

Academic Research Fleet
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$85.88	-	$77.80	-$8.08	-9.4%

The U.S. Academic Research Fleet (ARF) included 18 vessels in calendar year 2016 with the Office of Naval Research (ONR) delivering two new ocean class vessels into the fleet. The vessels in the ARF range in size, endurance, and capabilities, enabling NSF and other federally and state-funded scientists to conduct ocean science and technology research with a diverse fleet capable of operating in coastal and open ocean waters. Funding for ARF 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$82.79	-	$77.80	$77.80	$77.80	$77.80	$77.80	$77.80
Fleet Modernization								
Regional Class Research Vessel	3.09	-	-	-	-	-	-	-
Total, Academic Research Fleet	**$85.88**	**-**	**$77.80**	**$77.80**	**$77.80**	**$77.80**	**$77.80**	**$77.80**

[1] Outyear funding estimates are for planning purposes only.

ARF serves as the main platform for the collection of data, testing of hypotheses about the structure and dynamics of the ocean, and the development and testing of novel technological instrumentation. 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.

ARF is supported through an interagency partnership, principally with the Office of Naval Research (ONR) and the National Oceanic and Atmospheric Administration (NOAA). The operating costs for the fleet are divided proportionally among the vessel users based on usage; in CY 2016 NSF supported approximately 64 percent 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 NSF and other federal and state agencies. Within NSF,

[1] www.nopp.org/wp-content/uploads/2010/03/federal_oceanographic_fleet_status_report.pdf

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 Office of Polar Programs (OPP), 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 2018 funding level will support approximately 1,675 ship operating days, which reflects the entry of R/V *Neil Armstrong* and R/V *Sally Ride*, the two new vessels delivered by ONR in 2016, into the fleet.

Fleet Operations/Management and Oversight

- 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 day-rate negotiations for ARF, regardless of owner. In addition, NSF oversees the fleet through Business Systems Reviews, site visits, ship inspections, and participation at the UNOLS Council and various 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.

- After an in-depth review of the application of rate structures on ARF ship-related activities, NSF and ONR are in the process of transitioning the accounting of Fleet activities into a Specialized Service Facility in accordance with OMB’s Uniform Guidance for Federal Awards 2 CFR 200.468.

- 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 and technological 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 Oceanographic Fleet, which includes both the Academic Research Fleet and the survey ships. This report was updated in March of 2016 (http://www.nopp.org/wp-content/uploads/2016/06/federal_fleet_status_report_final_03.2016.pdf). 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

[2] https://obamawhitehouse.archives.gov/sites/default/files/national_ocean_policy_implementation_plan.pdf
[3] https://obamawhitehouse.archives.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.nopp.org/wp-content/uploads/2010/03/federal_oceanographic_fleet_status_report.pdf
[7] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

ships in all of the NAS-identified ocean science and technology 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. A Business Systems Review of one Academic Research Fleet operating institution was conducted in 2016.

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 (R&RA) 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 were 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 2016 update to the 2013 *Federal Oceanographic Fleet Status Report.* The RCRV would address requirements across government agencies for research vessels in support of ocean science research as discussed in the Fleet Status Report Update of 2016. Decisions on proceeding to further development stages will be based upon NSF, National Science Board (NSB), and interagency reviews. For additional information on RCRV please refer to the MREFC chapter.

- R/V *Sikuliaq*, formerly the Alaska Region Research Vessel (ARRV): The R/V *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* successfully completed ice trials in the Bering Sea and three science cruises in the Arctic Ocean. All final MREFC project activities were closed out under budget by March 31, 2016.

- Research in the Arctic is needed on topics ranging from natural resources, 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 and technology 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

[8] www.nsf.gov/pubs/2015/nsf15089/nsf15089.pdf

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 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. *ALVIN* continues to support science missions with approximately 100 dives per year.

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, with upcoming renewals planned for FY 2018. 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 *R/V Sikuliaq*, a re-compete clause in ten years (2024) was included in the initial cooperative agreement for operations. This clause will be added to all renewals of NSF owned vessels.

ARECIBO OBSERVATORY

$7,720,000
-$1,180,000 / -13.3%

Arecibo Observatory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$8.90	-	$7.72	-$1.18	-13.3%

The Arecibo Observatory (Arecibo) is a center for multidisciplinary research and education with world-class observational facilities. The observatory's principal facility is one of the world's largest single-dish radio/radar telescopes, 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 subrecipients Universities Space Research Association (USRA) and Universidad Metropolitana (UMET) under a cooperative agreement with NSF that initially ran from October 1, 2011 to September 30, 2016, and was extended by 18 months to March 31, 2018. 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.

Currently, Arecibo is staffed at approximately 120 full-time equivalent (FTE) employees, of which about 100 are funded by NSF. The remaining FTEs are supported by a grant from NASA, by the Angel Ramos Foundation Visitor Center, and by other funding sources. Staff include 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.

Total Obligations for the Arecibo Observatory
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (MPS)	$4.80	-	$3.90	$3.05	$2.13	$1.50	$1.13	$1.00
Operations & Maintenance (GEO)	4.10	-	3.82	3.03	2.13	1.50	1.13	1.00
Total, Arecibo	**$8.90**	-	**$7.72**	**$6.08**	**$4.25**	**$3.00**	**$2.25**	**$2.00**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement, initially scheduled to end in FY 2016, has been extended through 31 March 2018.

Arecibo is jointly supported by the NSF Directorate for Mathematical and Physical Sciences (MPS), Division of Astronomical Sciences (AST) and the NSF Directorate for Geosciences (GEO), Division of Atmospheric and Geospace Sciences (AGS). Planned AST support through FY 2018 is based on the 2006 AST Senior Review recommendations, an external review of the AST portfolio conducted in 2012, and guidance from a third-party cost review of AST facilities.

In 2012, the AST Portfolio Review Committee recommended "continued AST involvement in Arecibo…be re-evaluated later in the decade in light of the science opportunities and budget forecasts at that time."[9] The *New Worlds, New Horizons: Midterm Assessment* (August 15, 2016) reinforced this, with Recommendation 3.1 noting: "The NSF should proceed with divestment from ground-based facilities that have a lower scientific impact…."[10]

The Geospace Section (GS) Portfolio Review Committee was charged by the NSF Advisory Committee for Geosciences to review the most promising Geospace science strategies and critical capabilities and to reconcile these with the science goals described by the 2013 Decadal Survey for Solar and Space Physics. The GS is associated with AGS and its portfolio includes grant programs in upper-atmospheric sciences, space science and space weather. This GS portfolio review was carried out using the assumption of an inflation-adjusted, flat budget for GS over the next decade to FY 2026. The GS Portfolio Review Committee recommendations include the reduction of annual AGS Arecibo Observatory funding from $4.10 million to $1.10 million by 2020.

GEO commissioned a review from a second panel assembled by the National Academy of Science that assessed the process by which the GS Portfolio Review Committee reached their findings and recommendations. The panel published the results of this review in early 2017 and, for Arecibo, reiterated the recommendations GS Portfolio Review Committee.

Because of these potential changes, NSF is currently preparing an Environmental Impact Statement (EIS) to evaluate proposed operational changes at Arecibo due to funding constraints, pursuant to the National Environmental Policy Act (NEPA). NSF is also completing its compliance obligations with the National Historic Preservation Act (NHPA), and the Endangered Species Act (ESA). A draft version of the EIS (Draft EIS) was released on October 28, 2016.[11] In the Draft EIS, NSF evaluated the anticipated environmental impacts stemming from implementation of several proposed alternatives, including: (1) No-Action Alternative; (2) *Alternative 1* - Collaboration with interested parties for continued science-focused operations at Arecibo Observatory (identified in the Draft EIS as the Agency Preferred Alternative); (3) *Alternative 2* - Collaboration with interested parties for continued education-focused operations at Arecibo Observatory; (4) *Alternative 3* - Mothballing of facilities (suspension of operations in a manner such that operations could resume efficiently at some future date); (5) *Alternative 4* - Partial deconstruction and site restoration; and (6) *Alternative 5* - Full deconstruction and site restoration.

Following the 45-day public comment period that ended on December 12, 2016, NSF is preparing a Final EIS. Concurrent with the EIS process, NSF is working with consulting parties under Section 106 of the NHPA to find ways to avoid, minimize, or mitigate any adverse effects on nationally significant historic properties at Arecibo as a result of implementation of any of the proposed alternatives. Likewise, NSF is working with the U.S. Fish and Wildlife Service to evaluate the anticipated impacts from implementation of the proposed alternatives on threatened/endangered species and their habitats.

NSF issued a solicitation on January 25, 2017 requesting proposals to provide continued operations and management of Arecibo for five years, but at reduced funding. After the conclusion of NSF's compliance with federal statutes for the EIS, and review of responses to the solicitation, NSF will prepare a Record of Decision documenting its chosen course of action with regard to Arecibo Observatory.

<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 increased to $3.60 million

[9] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[10] www.nap.edu/read/23560/chapter/1
[11] www.nsf.gov/mps/ast/env_impact_reviews/arecibo/arecibo_drafteis.jsp

for FY 2013, with more observing time allocated to the NASA program. NASA support is expected to continue at approximately $3.60 million in FY 2018.

Education and Public Outreach (EPO): Arecibo hosts a Research Experiences for Undergraduates (REU) site, and Ph.D. students receive training through the use of the facility. Over 350 students have participated in REU programs at Arecibo. In collaboration with the National Radio Astronomy Observatory (NRAO), Arecibo holds a summer school on single-dish radio astronomy 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 were updated, and physical renovations to the visitor center building were completed in FY 2016. These improvements were funded by the Angel Ramos Foundation and the Ana G. Méndez University System, and were formally approved by the NSF. With funds received from the Puerto Rico Department of Education, Arecibo has hosted numerous teacher workshops 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.

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.*

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 75 percent of astronomy users conduct their observing remotely via networked control software, while radar observations typically employ on-site users.

Management and Oversight

- AST, $3.90 million: AST funding will maintain basic operations costs and science programs in passive radio astronomy. As recommended by the 2006 AST Senior Review, AST funding for Arecibo has been gradually reduced. The reduction will continue in FY18.
- AGS, $3.82 million: AGS funding will support basic operations costs and science programs in aeronomy and space physics, including space weather.
- NSF Structure: Ongoing oversight is provided by the lead NSF program officer in AST, in close cooperation with a 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 that arise, program officers work closely with other NSF offices. This includes the Division of Acquisition and Cooperative Support and the Large Facilities Office, both within the Office of Budget, Finance, and Award Management; and the Office of General Counsel. The AST and AGS program officers conduct periodic site visits and frequent,

regular, 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.
- Reviews:
  - A proposal review for the management and operations of Arecibo occurred 2010, resulting in an award to SRI (see above) from October 2011 to September 2016, extended by 18 months to March 31, 2018.
  - AST and AGS jointly conduct annual external reviews of Arecibo program plans; the most recent such review was held in January 2017.

<u>Renewal/Competition/Termination</u>

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 was in effect through September 30, 2016, and was extended through March 31, 2018. As discussed previously, the direction beyond that time will be determined after carrying out the EIS process and evaluating the responses to the solicitation for management and operations beyond March 31, 2018. As can be seen in the obligations table above, outyear funding estimates are reduced from recent levels and are consistent with the NSF funding profile provided in the FY 2017 management competition solicitation.

CORNELL HIGH ENERGY SYNCHROTRON SOURCE **$16,000,000**
- $4,030,000 / -20.1%

Cornell High Energy Synchrotron Source
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$20.03	-	$16.00	-4.03	-20.1%

The Cornell High Energy Synchrotron Source (CHESS) is a high-intensity, high-energy X-ray user facility in Ithaca, NY. 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).

With support from the state of New York, CHESS is currently upgrading the source ring to a high energy hard X-ray synchrotron source. In FY 2017, NSF conducted a review of the science case for the proposed new X-ray source, named CHESS-U, and determined that this upgrade would not provide a sufficiently unique facility to justify continued stewardship of the source by NSF. This led to the decision to continue funding CHESS operations until March 31, 2019 with a plan to accept a transition proposal in FY 2019. This proposal would establish a partnership model whereby NSF would consider investing in the most unique experimental components but no longer support full operation of the source. Within this FY 2018 allocation, the transition will begin one year early.

Total Obligations for CHESS
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (MPS)	$10.03	-	$8.00	$8.00	$5.00	$5.00	$5.00	$5.00
Operations & Maintenance (BIO)	5.00	-	4.00	-	-	-	-	-
Operations & Maintenance (ENG)	5.00	-	4.00	-	-	-	-	-
Total, CHESS	**$20.03**	**-**	**$16.00**	**$8.00**	**$5.00**	**$5.00**	**$5.00**	**$5.00**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2019. NSF will begin transition of CHESS from NSF stewardship to a partnership model in FY 2018, with future obligations dependent on review of a transition proposal.

CHESS is a national user facility accessed through a competitive proposal review process. 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 has developed 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. The CHESS education and outreach program annually impacts over 6,000 people of all ages, including over 1,300 visitors touring the Cornell facilities. Each year, about 60 Ph.D. degrees are 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, BIO, and ENG 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 Oversight 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, BIO, and ENG at NSF, as well as NIH program directors.
- External structure: The Cornell Laboratory of Accelerator-baSed Sciences and Education (CLASSE), which falls under 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, as well as the 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 composed of members from the research community, representatives from NIH attend these site visits. Recent and upcoming reviews include:
  - Review of science case for state funded upgrade of CHESS (CHESS-U), October 26-28, 2016.
  - Program Director site visit, October 2017.
  - Review of Transition Proposal, March 2018.

Renewal/Recompetition/Termination

The end date of the current CHESS award is March 2019. In FY 2017, NSF conducted a review focused on the science case for the state-supported on-going upgrade of CHESS. The outcome led to NSF's decision to transition from a stewardship role of CHESS to one focused on partnership to enable the best science. Initial plans were to accept a transition proposal in FY 2019. The current plan is for the transition to begin in FY 2018, or one year early. At the FY 2018 Request level, support will total $16.0 million with DMR providing $8.0 million and BIO and ENG providing $4.0 million each.

GEMINI OBSERVATORY **$21,030,000**

+$1,150,000 / 5.8%

Gemini Observatory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$19.88	-	$21.03	$1.15	5.8%

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 an elevation of 4,200 meters, 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 issues 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 national research agencies that currently form the Gemini international partnership include: NSF, the Canadian National Research Council (NRC), the Argentinean Ministerio de Ciencia, Tecnología e Innovación Productiva, the Brazilian Ministério da Ciência, Tecnologia e Inovação and the Chilean Comisión Nacional de Investigación Científica y Tecnológica (CONICYT). The five agencies are signatories to the Gemini International Agreement which covers all activities related to Gemini. The current Agreement covers the period January 1, 2016 through December 31, 2021.

The Gemini observatory helps educate astronomy and engineering students through undergraduate internship programs in both Hawaii and Chile. Gemini also provides an engaging focal point for public outreach and student training in all of the partner countries. Gemini-sponsored activities attract students and teachers at all levels of elementary through high school education; the unique Gemini-led *Journey Through the Universe* program in Hilo, Hawaii (now in its 13th year) and its sister activity, *Viaje al Universo* in La Serena, Chile, bring astronomy into the classroom through a week-long annual event that involves dozens of astronomers from Gemini as well as from many of the other astronomical facilities at each location. Gemini staff members also provide guidance and support to the ‘Imiloa Astronomy Center, a public facility in Hilo that seeks to advance the integration of science and indigenous culture through education.

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. Over the next 12 months Gemini will be upgrading the lasers at both observatories to more powerful and more reliable devices.

The observatory is actively developing new imagers and spectrometers. The state-of-the-art Gemini Planet Imager, GPI, is now in regular use for directly imaging planets orbiting nearby stars; a new spectrograph, the Gemini High-resolution Optical SpecTrograph (GHOST), a workhorse instrument for studying a vast array of astronomical objects, is nearing completion; and a contract has just been signed for a new 8-beam optical/infrared spectrograph, OCTOCAM, that will be used to characterize exotic transient phenomena discovered with the Large Synoptic Survey Telescope (LSST) in the 2020s. This latest instrument selection directly responds to the need for an LSST follow-up instrument, as recommended in the 2012 NSF/Division of Astronomical Sciences (AST) Portfolio Review report *Advancing Astronomy in the Coming Decade: Opportunities and Challenges* (discussed further below), in the 2015 National Academies report *Optimizing the U.S. Ground-Based Optical and Infrared* System, and in the 2016 KAVLI Futures Symposium report *Maximizing Science in the Era of LSST: A Community Based Study of Needed US OIR Capabilities.*

As noted earlier, 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 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.

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 the 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.

The Gemini North Telescope atop Mauna Kea in Hawaii. In this long-exposure photograph, the stars in the night sky appear as arcs due to the rotation of the earth. The reddish “beams” emanating from the top of the Gemini dome are produced by the laser used to support the observatory’s adaptive optics system. As the laser is tracked across the sky, following the target being observed, its narrow beam appears smudged in this time-lapse photograph. *Credit: J. Pollard/Gemini Observatory*

Total Obligations for the Gemini Observatory

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$19.88	-	$21.03	$21.66	$22.31	$22.98	$23.67	$23.67

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2022.

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 should complete a senior review before the mid-decade to determine which, if any, facilities 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 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*[13] 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), the NRC recommended that the U.S. increase its partner share in Gemini; therefore the FY 2018 Budget Request is higher than the amount recommended by the PRC.

The FY 2018 Request includes the full U.S. contribution to baseline operations at the level agreed to by the participants in the Gemini International Agreement ($19.12 million in FY 2018), with an additional contribution of $1.91 million to the Gemini Instrument Development Fund (equivalent to 10 percent of the operations contribution). Funding levels through FY 2021 have been agreed to by the current Gemini participants and are specified in a Gemini Board resolution from May 2015; the U.S. contributions provided for the out-years reflect a 3 percent increase per year for the period 2016-2021. No commitment has yet been made for FY 2022 and beyond, by any of the Gemini participants, though the FY 2022 figures denote a continuation of the 3 percent annual increase extended to the end of the current cooperative agreement.

Management and Oversight

- External Structure: The observatory is governed by the Gemini Board, which was established by the Gemini International 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. The Gemini Observatory 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.

- NSF Structure: NSF has one seat on the Gemini Board, currently occupied by the AST program officer

[12] www.nap.edu/catalog.php?record_id=12951
[13] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

responsible for Gemini programmatic oversight. An additional NSF staff member serves as the executive secretary to the board. 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, participates in various Gemini Board sponsored sub-committees, and approves funding actions, reports, and contracts. The program officer is also the current chair of the Gemini Finance Committee, a subcommittee of the Gemini Board that monitors and assesses the observatory's budget and provides guidance to the Gemini Board.

- Reviews: NSF conducts periodic reviews of the management and operation of the observatory, and of AURA's financial systems, often in collaboration with the Gemini Board. NSF has conducted Business System Reviews (BSRs) of the observatory and AURA's centralized administrative services in 2009 and 2013. In April 2017, NSF conducted a Gemini Accounting System Audit, and plans to conduct a new BSR in 2018.

Renewal/Competition/Termination

The United Kingdom withdrew from the Gemini partnership at the end of 2012 which required the observatory to adjust to an approximate 24 percent reduction in budget. More recently, Australia, a 6.3 percent partner in 2015, moved to a more limited participation on a year-to-year basis. South Korea has a similar arrangement (year-to-year) through the end of 2017, however, discussions with South Korea are currently underway regarding full partnership. The next participant assessment point is scheduled for 2018, at which time partners will establish their levels of participation in the Gemini Observatory beyond December 2021.

The recently expired (end of 2016) NSF cooperative agreement for managing the Gemini Observatory included a plan to negotiate the transition to the new operations model under the reduced budget described above. Reductions in project scope included a decreased instrument complement on each telescope, cost savings from a shift to remote telescope operations from the sea level base facilities in Hawaii and Chile, a redesign of the data archive, and a tighter focus on serving the partner user communities at the expense of internal scientific research activities. These and other transition projects have now been successfully completed.

Prior to the completion of the above transition program, recompetition 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. The National Science Board approved NSF's selection of AURA as the managing organization for the observatory in February 2016, under a new cooperative agreement that covers the period January 1, 2017 to December 31, 2022.

GEODESY ADVANCING GEOSCIENCES AND EARTHSCOPE $12,220,000

-$960,000 / -7.3%

Geodesy Advancing Geosciences and EarthScope

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$13.18	-	$12.22	-$0.96	-7.3%

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, a consortium of 113 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 105 associate members from foreign institutions. GAGE was formed in late FY 2013 from the geodetic component of the EarthScope facility and related geodetic facilities previous managed by UNAVCO. The FY 2018 Budget Request will allow GAGE to continue providing service to the community consistent with that in previous years.

Total Obligations for GAGE

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$13.18	-	$12.22	$12.22	$12.22	$12.22	$12.22	$12.22

[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

- The EarthScope Plate Boundary Observatory (PBO) includes more than 1,100 continuous Global Positioning System (GPS) stations (approximately 650 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 exceeds 90 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. More than 900 continuous GPS observations from around the world are now maintained, monitored, and data compiled into the GAGE data system. GAGE supports 59 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 Caribbean region GPS and meteorological sensor network (COCONet) of more than 100 stations that support tectonic, volcano, tropical storm, and sea level change investigations.
- Community GPS receiver and geodetic technology pool includes a pool of over 690 GPS receivers, ancillary equipment, and six terrestrial laser scanners, 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.
- 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 233 terabytes of data from 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 100 km 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.

Beside 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 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) in the Directorate for Geosciences, 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 Integrated Activities 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 113 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 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 and concurred with by the National Science Board in December 2009, NSF solicited proposals to manage and operate one or more components of a new facility to support the Earth sciences research and education community. These components are currently supported by GAGE and the related Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE). The new distributed, multi-user, national facility would support the development, deployment, management, and operational support of modern geodetic, seismic, and related geophysical instrumentation and provide services to serve national goals in basic research and education in the Earth sciences. NSF is currently reviewing proposals received in response to this facility solicitation.

ICECUBE NEUTRINO OBSERVATORY $7,000,000

-$1,710,000 / -19.6%

IceCube Neutrino Observatory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actuals Amount	Percent
$8.71	-	$7.00	-$1.71	-19.6%

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 near distant astrophysical accelerators like black holes and neutron stars, the so-called cosmic neutrinos. Astrophysical neutrinos remain the dominant component above 10 TeV. The number of these cosmic neutrinos (100 TeV - 10 PeV) detected by IceCube has already exceeded 50.

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. The DCA closes the energy gap between the IceCube Neutrino Observatory and the Super-Kamiokande detector in Japan, and allows effective observations of high-energy neutrinos entering from the sky of the southern hemisphere.

Total Obligations for IceCube

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (GEO)	$5.23	-	$3.50	$3.50	$3.50	$3.50	$3.50	$3.50
Operations & Maintenance (MPS)	3.48	-	3.50	3.50	3.50	3.50	3.50	3.50
Total, IceCube	**$8.71**	**-**	**$7.00**	**$7.00**	**$7.00**	**$7.00**	**$7.00**	**$7.00**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2021.

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.

Management and Oversight

- NSF Structure: Oversight of the IceCube Neutrino Observatory is the joint responsibility of the Geosciences Directorate's Office of Polar Programs (OPP) 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 OPP 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.

Operations Costs

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 (approximately $4.0 million annually provided jointly by GEO and MPS).

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 future leaders in astrophysics, including undergraduate students, graduate students, and postdoctoral research associates; K-12 teacher scientific and 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 serving institutions; and enhanced public understanding of science through broadcast media and museum exhibits (such as the Adler Planetarium in Chicago, Illinois) 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 re-competed the IceCube operations and maintenance award in FY 2016. The new award was issued on April 1, 2016 for 60 months. Actual obligations for FY 2016 are higher than original estimates due to the extension of the previous cooperative agreement to allow time for the 2016 competition.

INTERNATIONAL OCEAN DISCOVERY PROGRAM

$48,000,000
$0 / 0.0%

International Ocean Discovery Program

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$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, structure, and behavior 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$48.00	-	$48.00	$48.00	$48.00	$48.00	$48.00	$48.00

[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. The FY 2018 Request of $48.0 million for operations and maintenance of the *JOIDES Resolution* maintains level funding for this international research facility, and will continue to enable full-schedule vessel operations. 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 at minimal cost 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, funded separately through OCE.

The IODP scientific program emphasizes 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 of which is 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, Canada, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, 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 3,700 scientists from 52 nations have participated on Ocean Drilling Program, Integrated Ocean Drilling Program, and International Ocean Discovery Program expeditions since 1985, including approximately 1,600 U.S. scientists from over 150 universities, government agencies, and industrial research laboratories. Samples and data have been distributed to well over 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 1.5 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. NSF is a member of the JRFB.
- 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 occurred 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).

LARGE HADRON COLLIDER $22,300,000 +$2,300,000 / 11.5%

Large Hadron Collider
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request[1]	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$20.00	-	$22.30	$2.30	11.5%

[1] Includes funding for High-Lumosity LHC Upgrade planning.

The Large Hadron Collider (LHC), an international instrument 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 proton beams with a design energy of 7 TeV (1TeV=10^{12} electron volts) per beam. 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 TeV per beam, exploring a new energy region not accessible during Run 1.

Four large particle detectors collect the data delivered by the LHC. They characterize the reaction products from high-energy proton-proton and heavy ion beam collisions. These 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 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. Its existence was a prediction of the theoretical framework describing the origin of the masses of elementary particles. The experimental confirmation of this theory was recognized by the award of the 2013 Nobel Prize in Physics to Francois Englert and Peter Higgs. Another important discovery was announced on July 14, 2015, when 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. On June 28, 2016 the same collaboration reported the observation of tetraquark states, another novel aggregation of quarks into four-quark elementary particles.

The resumed program of operation, which began 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)

	FY2016 Actual	FY2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance[2]	$20.00	-	$22.30	$22.30	$20.00	$20.00	$20.00	$20.00

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreements end in December 2021 (CMS) and January 2022 (ATLAS).

[2] FY 2018 and FY 2019 include funding for High-Lumosity LHC Upgrade planning.

A worldwide cyber-infrastructure, 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 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 research program, within a global context, should be continued support for involvement in the LHC program. Within the scope of supported activities, they recommended a further planned upgrade of the accelerator to very high luminosity (nearly ten times the luminosity of initial operation). The high-luminosity upgrade will commence operation in mid-2026, and will facilitate 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 now working with the ATLAS and CMS detector collaborations to plan for this possibility. If approved, construction and fabrication activities would begin in FY 2020 in order to be ready for installation activities scheduled for 2024.

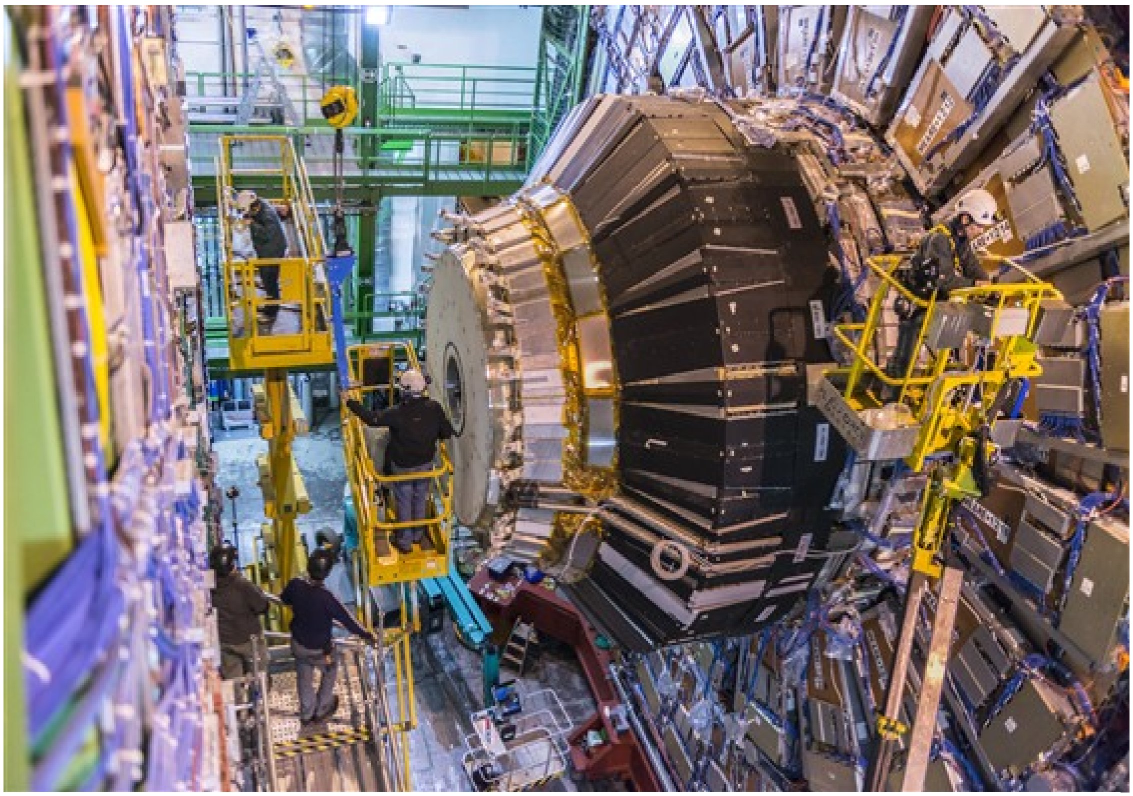
Through the participation of young investigators, graduate students, undergraduates, and minority-serving institutions in this international project, LHC serves the goal of helping to produce a diverse, globally-oriented workforce of scientists and engineers. Innovative education and outreach activities 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 is responsible for day-to-day project oversight. The Division of Acquisition and Cooperative Support provides financial and administrative support. An Integrated Project Team, consisting of representatives from the Mathematical and Physical Science Directorate, other experienced program officers, the Large Facilities Office, and other areas of the Office of Budget, Finance, and Award Management, contribute to the 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 Stony Brook 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 conduct separate and joint external reviews of the detector upgrade activities so that each agency is fully cognizant of the activities of the other partner. The most recent major joint management/technical review was held in January 2017. Two JOG review meetings per year monitor overall program management. The most recent JOG was held in April 2017.

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. Through an internal competition process among the research community, the ATLAS collaboration selected Stony Brook University to lead NSF-funded operations, while Princeton University was re-selected to continue to lead CMS operation. The U.S. ATLAS and CMS collaborations submitted renewal proposals that were successfully reviewed and approved. The new awards took effect in early 2017. The cooperative agreements end in December 2021 (CMS) and January 2022 (ATLAS).



The 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$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 black holes, will produce gravitational radiation. On Sept. 14, 2015, the Laser Interferometer Gravitational-Wave Observatory (LIGO) directly observed gravitational radiation from a black-hole merger, verifying this 100-year-old prediction. This is an achievement of historic importance for fundamental physics, astrophysics, and astronomy, as it opens an entirely new observational window on the universe. This achievement was announced to the world in a series of international press conferences on February 11, 2016. LIGO announced detection of a second black-hole merger on June 15, 2016. Its second observing run, now underway, holds the possibility of further detections.

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, an L-shaped vacuum chamber, with two 4-km long arms joined at right angles, houses an optical interferometer. The interferometers are used to measure minute relative changes in the distances between the vertex of the L and mirrors at the ends of the arms that are caused by a passing gravitational wave. A passing gravitational wave causes the distance along one arm to lengthen while the other arm shrinks during one half cycle of the wave, and then the first arm shrinks while the other arm lengthens during the second half cycle. 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 amplitude of the length change over the 4-km length is only about 1/1000th the diameter of a proton. LIGO's 4-km length was chosen to make the expected signal as large as possible within terrestrial and financial constraints. (Longer arms would result in a bigger signal, but would entail larger construction costs.) Looking for coincident signals from both interferometers increases LIGO's ability to discriminate a gravitational wave signal from local sources of noise that can mimic the signal.

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 greatly enhance LIGO's ability to locate gravitational wave sources on the sky, facilitating follow-up investigations using optical and radio telescopes. The prospect of obtaining complementary gravitational wave and electromagnetic signals from the same source is extremely exciting, as it may significantly increase our understanding of supernovae and neutron stars. Such scientific prospects help motivate the NSF Big Idea Windows on the Universe.

The Advanced LIGO upgrade, funded through the MREFC account, resulted in the design, fabrication, and installation of improved apparatus that is expected to increase LIGO's sensitivity 10-fold over a multi-year tune-up period.

Total Obligations for LIGO

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$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.

LIGO is pursuing an integrated program of periodic scientific operation of the LIGO observatories, interleaved with engineering studies that continue to enhance operating performance. LIGO's operating budget supported the initial commissioning of this apparatus. Following completion of installation of the Advanced LIGO apparatus in March 2015, LIGO scientists and engineers were able to achieve about four times LIGO's initial sensitivity by September 2015 in order to make the historic first detection of gravitational waves. Since then, after further commissioning, LIGO has been able to achieve more than a six-fold increase in sensitivity. LIGO is now in the midst of a nine-month long observing run that will search for more gravitational waves through the end of August 2017.

The operations budget also supports basic infrastructure maintenance, analysis, and dissemination of data obtained from the interferometers, and maintenance of computational resources for data storage and analysis. Operations funding also enables strategic research and development in instrument science that is expected to lead to longer-term enhancements to operational performance.

A small part of the operations budget supports education and outreach activities. 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. Its 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. The LIGO Hanford Observatory also promotes a highly successful program of outreach to K-12 students and the general public in that region.

LIGO created a number of connections to industry in order to achieve the demanding technical performance requirements needed to detect gravitational waves. 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 precision dielectric optical coatings). Other cases have resulted in patents and commercial products (in-vacuum electrical connectors, high power electro-optic modulators).

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. These include 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 program funds.

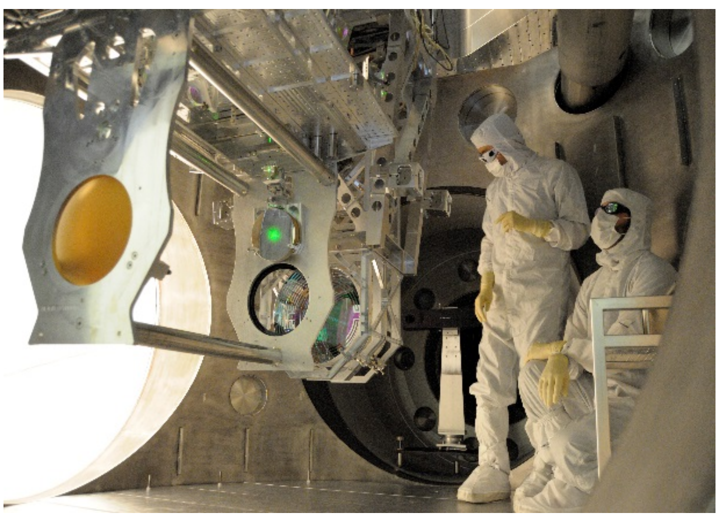
NSF continually assesses the appropriate level of financial support by monitoring actual expenditures contained in quarterly activity-based financial reports from LIGO and through annual external reviews of operation.

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). The program director consults regularly with representatives from the NSF Large Facilities Office, the MPS Facilities Coordinator, and the NSF Office of Grants and Agreements.
- External Structure: LIGO is managed by the 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: Reviews of observatory operation are held annually. Special purpose reviews using external expert panels have also been held as needed, examining topics such as long-term storage of the interferometer components set aside for possible deployment to India, LIGO computing plans, and LIGO ultra-high vacuum system needs. The last annual review was held in June 2016. A vacuum review is planned for May 2017 and an operations review in June 2017.

Renewal/Recompetition/Termination:

LIGO began operating under a five-year cooperative agreement in early FY 2009, which ran concurrently with 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 conducted a detailed consideration of whether or not to recompete the management of LIGO and determined that it would be in the best interest of U.S. science and engineering to renew the LIGO operating award at the end of FY 2018. Accordingly, NSF has requested the awardee submit a renewal proposal for review early in FY 2018. 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 **$34,770,000** **-$570,000 / -1.6%**

National High Magnetic Field Laboratory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$35.34	-	$34.77	-0.57	-1.6%

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 1,500 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 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 for user access; this world record has been held for more than a decade. Recently, NHMFL's new 36 Tesla Series-Connected Hybrid (SCH) magnet has reached its performance specification of 1 ppm stability and homogeneity, enabling the world's first nuclear magnetic resonance (NMR) spectrum at 1.5 GHz. The previous record was set at 1.0 GHz. These magnets enable scientists to gain new insights into the electronic structures of novel materials such as graphene, topological insulators, and high temperature superconductors. 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 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 FT-ICR instrument opened for user operations in October 2015. This 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. The system impacts a broad array of research areas, such as chemistry, molecular biology, and earth science.

NHMFL is seeking funding renewal in FY 2018. The renewal proposal will allow the facility to continue operations, focus on transformational next generation magnet technology development, and further strengthen user support, education, training, and in-house research. The FY 2018 Budget Request is consistent with the very positive external review of the renewal proposal. Pending a recommendation to, and approval by, the National Science Board, NSF expects to fund the next cooperative agreement in FY 2018.

Total Obligations for NHMFL

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (DMR)	$33.42	-	$33.04	$33.04	$33.04	$33.04	$33.04	$33.04
Operations & Maintenance (CHE)	1.92	-	1.73	1.73	1.73	1.73	1.73	1.73
Total, NHMFL	**$35.34**	**-**	**$34.77**	**$34.77**	**$34.77**	**$34.77**	**$34.77**	**$34.77**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2017. NSF is reviewing a renewal proposal for FY 2018.

A potential impact of continued investment is the successful construction of a high field all-superconducting magnet that would make high magnetic fields attainable at lower operating costs than the current technology. This would open the door for many laboratories across the Nation to have access to 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. A major scientific impact of NHMFL for the coming years is expected to come from research on quantum materials conducted by users using the record-setting magnets at NHMFL, building on the recent achievements at NHMFL, such as the observation of Hofstadter's butterfly and fractionally quantized states in graphene; and quantum oscillations from surface states of topological insulators. 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, which may result in new insights into mapping the brain and neuroscience.

NHMFL collaborates with more than 60 private sector companies as well as national laboratories. These include 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 (CIRL) 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 NHMFL executive committee, NHMFL science council, and NHMFL diversity committee and recommendations from an external advisory committee and the users' executive committee.
- 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*[14] 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 continues to inform future plans 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:
  - Renewal proposal site visit, August 29-31, 2016.
  - NSF program director site visit, November 2017.
  - Site visit review with external panel of experts, October 2018.

Renewal/Recompetition/Termination

The end date of the current award is December 31, 2017. In May 2015, the National Science Board determined that it was in the best interest of the U.S. science and engineering to renew rather than recompete the NHMFL award. A renewal proposal was submitted in May 2016 that has been reviewed by external experts and is currently under internal consideration. Pending a recommendation to, and approval by, the National Science Board, NSF expects to fund the next cooperative agreement in FY 2018.

The National High Magnetic Field Laboratory, Tallahassee, Florida site. *Credit: NHMFL*

[14] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states

NATIONAL NANOTECHNOLOGY COORDINATED INFRASTRUCTURE $14,780,000 -$1,550,000 /-9.5%

National Nanotechnology Coordinated Infrastructure
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$16.33	-	$14.78	-$1.55	-9.5%

The National Nanotechnology Coordinated Infrastructure (NNCI) program was established in FY 2015 as the successor to the National Nanotechnology Infrastructure Network (NNIN). NNCI comprises 16 independent awards to universities around the Nation as user facility sites in nanotechnology. The NNCI sites provide the Nation's researchers in academia, small and large companies, and government with open access to leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering, and technology, thus helping to catalyze new discoveries in science and engineering and to stimulate technological innovation. 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, thereby providing more flexibility in awardee selection and management, and more agility in addressing emerging user facility needs in nanoscale research and education.

A Coordinating Office at Georgia Technological University was selected in FY 2016 through externally reviewed proposals from among the awarded sites to enhance the impact of NNCI as a national infrastructure network of user facility sites. The Director of the Coordinating Office is a key individual for developing management strategies and operational plans in concert with the Site Directors of the individual user facilities, and serves as a principal contact person with NSF. The individual NNCI sites have autonomy in their operation and management, but are required to act in concert with the Coordinating Office. The Coordinating Office is establishing a comprehensive web portal (www.NNCI.net) to ensure close linkage among the individual facility websites to present a unified face to the user community of overall tools, instruments, and capabilities. It is harmonizing capabilities for modeling and simulation across sites and interaction with NanoHUB of the NSF-supported Network for Computational Nanotechnology (NCN). It is coordinating and disseminating best practices for national-level education and outreach programs, as well as instruction across sites in social and ethical implications of nanotechnology. It is establishing uniform methods for assessment and quantifiable metrics of site performance and impact. It is also engaging 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 broad scope of NNCI sites includes materials, structures, devices, and systems in areas of physics, chemistry, materials sciences, mechanical systems, geosciences, geophysical, geochemical, environmental sciences, biology, life sciences, and synthetics biology. Also included are: fabrication in soft matter, including biological interfaces; biomedicine; electronics; optics; magnetics; molecular synthesis and molecular scale devices; and manufacturing concepts. Modeling and simulation, social and ethical implications of nanotechnology, and education and outreach are additional areas. 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 universities and other resources to grow the numbers of external users, including users from companies and academia. NNCI 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.

Nanotechnology facilities provide unique opportunities to infuse innovative education with research at the frontiers of the field. NNCI sites are providing focused strategies for integrating pioneering science and engineering with education, including plans for assessing effectiveness and spreading promising practices. NNCI 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.

During their first full year of operation, from October 2015 through September 2016, NNCI sites have served a total of 10,675 unique users who performed a significant part of their experimental work using NNCI facilities. Of these, 2,561 (24 percent) were external users: 1,151 external academic, and 1,410 from industry.

Total Obligations for NNCI

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Estimates[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations and Maintenance	$16.33	-	$14.78	$15.46	$15.46	$15.46	$15.46	$15.46

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2019.

<u>Management and Oversight</u>

- 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 NNCI Coordinating Office is led by a Director, Deputy Director, and three Associate Directors who manage the network in specific areas: education and outreach programs, societal and ethical implications (SEI) activities, and computational activities and facilitates interactions with nanoHUB/NCN at Purdue University. The core staff is guided by an Executive Committee which includes the 16 NNCI site directors. The Executive Committee meets monthly via teleconference/WebEx and annually in person at the NNCI Conference. The Executive Committee and Coordinating Office are advised by an External Advisory Board comprised of members representing industry, academia, government, education and outreach, SEI, computation and non-traditional disciplines in nanoscience and nanoengineering. Several subcommittees of the Executive Committee have been formed to address high-level issues related to the NNCI network, such as new equipment and research opportunities, workforce development, diversity, and building the user base. An annual NNCI Conference organized by the NNCI CO will be held at different network sites to highlight the research supported by the NNCI facilities and to provide a venue to share best practices.
- Reviews: Reviews are being conducted through annual reverse site reviews 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.

<u>Renewal/Competition/Termination</u>

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 $23,000,000

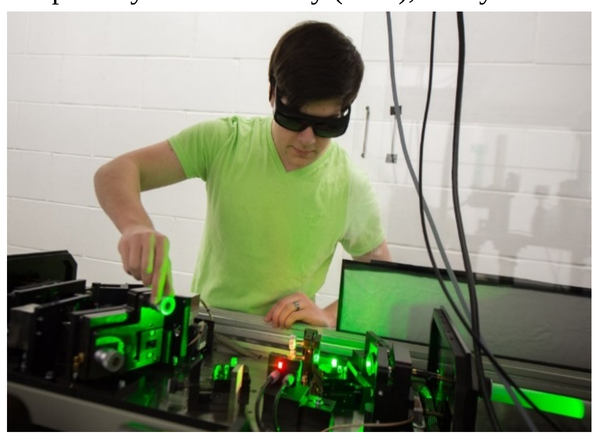
-$1,000,000 / -4.2%

National Superconducting Cyclotron Laboratory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$24.00	-	$23.00	-$1.00	-4.2%

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 a world leader in nuclear physics with the unique capability of producing radioactive beams at energies relevant to nuclear astrophysics. Funding for NSCL also supports the research program of the MSU nuclear science faculty.

NSCL scientists employ a range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Applications of research conducted at NSCL benefit society in numerous areas, including studies on the effects of ionizing radiation on DNA, tests of detectors to be used in space missions, development of data acquisition systems and software, and homeland security. The K500 was the first cyclotron to use superconducting magnets, and the 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. NSCL is the only facility in the world to provide radioactive beams in this energy regime. Nearly one third of recently proposed experiments will use the ReA3. 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 fifteen days.



Graduate student Andrew Miller aligning instrumentation on an optical table. *Credit: NSCL and MSU*

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.

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.

Total Obligations for NSCL

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$24.00	-	$23.00	$24.50	$24.50	$24.50	-	-

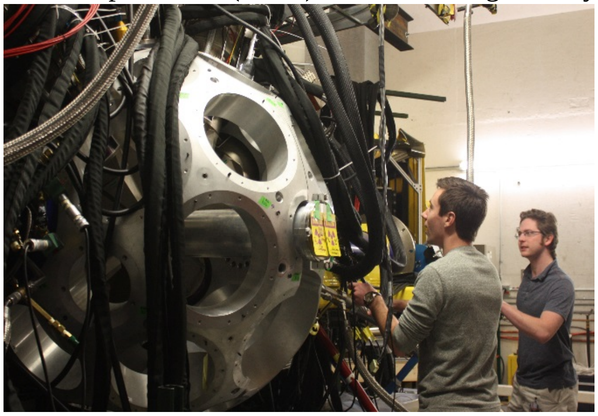
[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2021, after which the NSF-managed NSCL will transition to the DOE-managed FRIB.

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 the in-house research programs.
- External Structure: MSU provides additional support for NSCL, which is managed by a director and three associate directors (experimental research, education & outreach, and operations) as well as a chief scientist. The director has the 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 once a year and the beam hour backlog is no longer than two years. Optimally the laboratory can provide about 5,000 beam hours to the scientific community each year, with actual output depending upon facility reliability factors and available funds.
- Reviews:
  - An in-depth review in FY 2016 covered results and achievements related to intellectual merit and broader impacts for the past four years (FY 2012-FY 2015) as well as a review of proposed research, operations, and maintenance funding for the next five years (FY 2017-FY 2021).
  - The most recent regular annual review took place in April 2017.

Renewal/Recompetition/Termination

With the approval of the National Science Board, NSF established a cooperative agreement with MSU for a five-year renewal award to support the research program and operation of NSCL from FY 2016 through FY 2021. 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 to 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 this transfer of facility stewardship.



Postdoc Joe Belarge and graduate student Eric Lunderberg set up GRETINA (Gamma-Ray Energy Tracking In-beam Nuclear Array) for an experiment. *Credit: NSCL and MSU.*

NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE **$11,750,000**
-$1,250,000 / -9.6%

Natural Hazards Engineering Research Infrastructure
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$13.00	-	$11.75	-$1.25	-9.6%

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.

NHERI is a distributed, multi-user, national research facility that provides the natural hazards engineering research community with access to research infrastructure (earthquake and wind engineering experimental facilities; post-disaster, rapid response research (RAPID) facility; cyberinfrastructure; computational modeling and simulation tools; and research data), coupled with education and community outreach activities. Building upon NEES, NHERI enables 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 risk reduction. Research conducted using NHERI supports two federal interagency programs: the National Earthquake Hazards Reduction Program and the National Windstorm Impact Reduction Program.

During FY 2015 and FY 2016, NHERI was established by NSF through eleven cooperative agreements:
- Network Coordination Office (NCO) at Purdue University,
- Cyberinfrastructure (CI) at the University of Texas at Austin,
- Computational Modeling and Simulation Center (SimCenter) at the University of California, Berkeley,
- 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,
- Large, Mobile Dynamic Shakers for Field Testing at the University of Texas at Austin, and
- RAPID Facility at the University of Washington.

The NCO serves as the national and international scientific leader, community focal point, and network-wide coordinator for NHERI governance and community-building activities. Key activities 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 experimental facilities, leading development of a community science plan, running NHERI-wide education and community outreach programs, and building strategic partnerships. The NHERI awardees and the natural hazards engineering community 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.

The CI awardee serves 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 (Data Depot); software service delivery platform with computational modeling, simulation, and educational tools; collaboration tools; access to high performance computing resources; and user training and support. The CI awardee also establishes and implements the NHERI-wide cybersecurity plan with all NHERI awardees.

The SimCenter is developing 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's tools will be integrated into the CI awardee's software service delivery platform.

The experimental facilities 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. Data generated by these experimental resources and their users are archived and shared in the publicly accessible NHERI Data Depot.

Along with direct operations and maintenance support for NHERI awardees, NSF provides separate support for research to be conducted at the NEHRI experimental facilities through ongoing research and education programs. The support for such activities is primarily provided through the Engineering for Natural Hazards (ENH) core research program in the Civil, Mechanical and Manufacturing Innovation (CMMI) division in the Directorate for Engineering (ENG). The ENH program supports fundamental research in single and multi-hazard engineering involving experimental and computational simulations at the NHERI facilities, addressing important challenges in mitigating the impact of natural hazards on constructed civil infrastructure. With the aim of integrating research and education, NHERI engages students through on-site use of experimental facilities, telepresence technology, experimental and simulation data, and computational resources. Coordinated by the NCO, starting in FY 2017, NHERI awardees also will run an annual Research Experiences for Undergraduates (REU) program and a Summer Institute.

Total Obligations for NHERI

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Estimates[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations and Maintenance	$13.00	-	$11.75	$12.50	$12.00	$12.00	$12.00	$12.00

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2019.

Management and Oversight

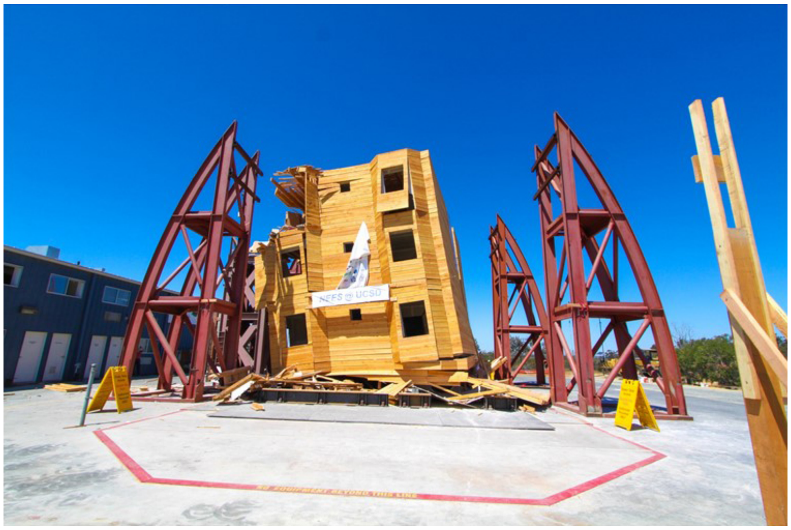
- NSF Structure: The NSF program officer for NHERI is located within ENG/CMMI. The Office Head of the Large Facilities Office in the Office of Budget, Finance and Award Management provides advice and assistance.
- External Structure: Each NHERI awardee is led by a principal investigator (PI), who is responsible for the overall award operations. The NCO awardee coordinates NHERI governance and network activities. Governance is 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, to be conducted within the first two years of the award.

Renewal/Competition/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.[15] 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 successor 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.[16] The plan would result in a lower 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.[17]
- In February 2013, NSF released solicitation NSF 13-537 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. The NCO, working with the natural hazards engineering research and education community, is developing the 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.

[15] http://nsf.gov/pubs/2010/nsf10071/nsf10071.jsp
[16] www.nsf.gov/pubs/2012/nsf12107/nsf12107.jsp
[17] www.nist.gov/customcf/get_pdf.cfm?pub_id=915541



The University of California, San Diego (UCSD) outdoor shake table allows large structures to be tested against seismic activity. Here, a wooden building shows damage after testing on the UCSD shake table.
Credit: UCSD/Jacobs School of Engineering

OCEAN OBSERVATORIES INITIATIVE

$31,000,000
-$23,980,000/ -43.6%

Ocean Observatories Initiative
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$54.98	-	$31.00	-$23.98	-43.6%

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 management and operation phase and is now referred to as the OOI Program.

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.

- *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

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 Management & Operation (M&O) budget for FY 2016 was $54.98 million.

The planned FY 2018 budget is $31.0 million. The scope of OOI activities at this funding level will be determined through the ongoing re-competition for a new management and operations award as described below in the Renewal/Recompetition/Termination section. The solicitation requests submission of proposals which include the costs for all parts, labor, equipment, ship time, and cyberinfrastructure to manage, operate, and maintain the OOI. Planned OOI Program adjustments include suspension of all Global Array operations and streamlined cyberinfrastructure and management oversight. Deployed Coastal OOI instruments are visited and replaced twice per year.

Total Obligations for OOI

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$55.00	-	$31.00	$31.00	$31.00	$31.00	$31.00	$31.00

[1] Outyear funding estimates are for planning purposes only.

The Consortium for Ocean Leadership (COL) is the current awardee for OOI operations and maintenance, but has publicly announced they will not be part of the recompetition. COL has major sub-awardees on the program 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: The OOI Program has a Science Oversight Committee (SOC) which provides input and guidance internally to Ocean Leadership for OOI infrastructure planning and management. In FY 2017, NSF established the nine member "Ocean Observatories Initiative Facility Board' (OOIFB) to provide input and guidance regarding the management and operation of the OOI. The OOIFB is independent of the SOC.
- Reviews: In December 2016, NSF conducted a review of the OOI Cyberinfrastructure component. NSF is considering a management and operations review in calendar year 2017 before the award end date of December 31, 2017.

Operations Costs

Management and operations 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 GEO's Division of Integrative and Collaborative Education and Research (ICER) from FY 2015-FY 2017 (now completed). 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 is producing 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 internal OOI Science Oversight Committee actively conducts outreach activities regarding the ocean science datasets to researchers, public and education users.

Renewal/Recompetition/Termination

The OOI management and operation cooperative agreement with COL ends December 31, 2017. A re-competition for the award was initiated in FY 2016 and is planned for completion by December 31, 2017.

POLAR FACILITIES AND LOGISTICS $284,960,000
-$23,360,000 / -7.6%

Polar Facilities and Logistics
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
Polar Facilities	$196.53	-	$177.85	-$18.68	-9.5%
Polar Logistics	111.79	-	107.11	-4.68	-4.2%
Total, Polar Facilities and Logistics	**$308.32**	**-**	**$284.96**	**-$23.36**	**-7.6%**

Polar Facilities
The Office of Polar Programs (OPP) 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), OPP supports the relay of real-time satellite-based weather information that informs global forecasting. In addition, OPP 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. OPP 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 OPP, 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Antarctic Infrastructure and Logistics	$196.53	-	$177.85	$177.85	$177.85	$177.85	$177.85	$177.85
Total, Polar Facilities	**$196.53**	**-**	**$177.85**	**$177.85**	**$177.85**	**$177.85**	**$177.85**	**$177.85**

[1] Outyear funding estimates are for planning purposes only.

OPP 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* returned to service in 2014 and is successfully providing annual icebreaking services for the McMurdo Station resupply effort.

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: OPP staff, including subject matter experts in operational and scientific disciplines, have overall responsibility for funding and managing Polar Facilities under the USAP; NSF budgets for and manages USAP on behalf of the Nation. This includes planning all activities and overseeing contractors. OPP'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/on Antarctica and the Southern Ocean. Research is conducted in a broad array of geo- and bio- sciences, including earth system science, and 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 prime support contract is currently held by Leidos Innovations Corporation. There are many separate subcontractors for supplies and technical services, and other services are procured through separate competitively-bid contracts.
- Reviews: OPP 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 OPP and the Office of Budget, Finance, and Award Management (BFA). In addition, OPP's performance is reviewed externally by Committees of Visitors and the Office of Polar Programs Advisory Committee. The USAP Blue Ribbon Panel (BRP) released a report on its review of the program in July 2012.[18] The NSF response to the USAP BRP report was released in March 2013.[19]

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 moving toward the final stages of design. The AIMS project will redevelop McMurdo Station to be a consolidated, more efficient facility. Also included are utilities distribution and fire protection. Plans are under development to upgrade satellite communications systems to support operations and research and to replace the Palmer Station pier to ensure long-term access to unique research in the peninsula region.

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[18] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp

[19] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/nsf_brp_response.pdf

<u>Renewal/Re-competition/Termination</u>

- In FY 2012, Lockheed Martin Corporation, now the Leidos Innovations 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. A five-year contract for fixed-wing aviation services, currently held by Kenn Borek Air of Calgary, Canada, is now under competition.
- 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
U.S. Antarctic Logistical Support	$67.52	-	$71.00	$71.00	$71.00	$71.00	$71.00	$71.00
Arctic Research Support and Logistics	44.27	-	36.11	36.11	36.11	36.11	36.11	36.11
Total, Polar Logistics	**$111.79**	**-**	**$107.11**	**$107.11**	**$107.11**	**$107.11**	**$107.11**	**$107.11**

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 through the Space and Naval Warfare Systems Command; 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 OPP 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. In FY 2016, the Directorate for Biological Science's (BIO) Division of Environmental Biology provided funding, approximately $164,000, through OPP's Arctic support contractor CH2M Hill and through the University of Alaska, Fairbanks for ongoing logistical support for two BIO funded projects in Alaska.

Management and Oversight

- NSF Structure: OPP 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: OPP 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 OPP and BFA. OPP's performance is externally reviewed by Committees of Visitors and the Office of Polar Programs Advisory Committee.

Current Status

All facilities (stations, research vessels, and field camps) are currently operating as normal.

Renewal/Re-competition/Termination

NSF re-competed 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 $24,190,000 -$1,450,000 / -5.7%

Seismological Facilities for the Advancement of Geoscience and EarthScope
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$25.64	-	$24.19	-$1.45	-5.7%

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 124 U.S. universities and non-profit institutions with research and teaching programs in seismology, 21 educational affiliates, three U.S. affiliates, and 127 foreign affiliates. SAGE was formed in late FY 2013 from the seismic components of the EarthScope facility and seismic facilities previously managed by IRIS. The FY 2018 Budget 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$25.64	-	$24.19	$24.19	$24.19	$24.19	$24.19	$24.19

[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.
- 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 430 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 2016, more than 17,000 unique users downloaded over 130 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 OPP provide most of the funds, totaling approximately $15.0 million annually, 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: The Division of Earth Sciences (EAR) in the Directorate for Geosciences, 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 124 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 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.

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 solicited proposals to manage and operate one or more components of a new facility to support the Earth sciences research and education community. These components are currently supported by SAGE and the related Geodesy Advancing Geoscience and EarthScope (GAGE). The new distributed, multi-user, national facility would support the development, deployment, management, and operational support of modern geodetic, seismic, and related geophysical instrumentation and provide services to serve national goals in basic research and education in the Earth sciences. NSF is currently reviewing proposals received in response to this facility solicitation.

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCs)

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH $89,900,000

-$15,700,000 / -14.9%

National Center for Atmospheric Research
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$105.60	-	$89.90	-$15.70	-14.9%

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 110 degree-granting academic institutions.

As of December 2016, NCAR supported a total of 729.9 full time equivalents (FTEs), of which 331.1 are funded under the NSF primary award to UCAR.

Number of FTEs Supported at NCAR

FTEs	Primary Award[1]	All Funding
Career Scientists	71.4	100.6
Scientific Support[2]	229.2	500.9
Other Staff[3]	30.5	128.4
Total	**331.1**	**729.9**

[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 world-class research programs, service, and facilities that enable the research community to advance our understanding of the sun-atmosphere system. These include the NCAR-Wyoming Supercomputing Center, the Mauna Loa Solar Observatory, two research aircraft, a transportable ground-based radar system, atmospheric sounder, and other surface sensing systems.

Total Obligations for NCAR

(Dollars in Millions)

	FY 2016 Actual[1]	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[2] FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Aircraft Support	$9.96	-	$8.50	$8.50	$8.50	$8.50	$8.50	$8.50
Computational Infrastructure	33.88	-	28.90	$28.90	28.90	28.90	28.90	28.90
Other Facility Support	15.31	-	13.00	$13.00	13.00	13.00	13.00	13.00
Research & Education Support	46.45	-	39.50	$39.50	39.50	39.50	39.50	39.50
Total, NCAR	**$105.60**	**-**	**$89.90**	**$89.90**	**$89.90**	**$89.90**	**$89.90**	**$89.90**

[1] Total includes $5.90 million funding for FY 2017 activities.

[2] 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 2016, NCAR received approximately $41.7 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 $21.6 million from non-federal sources.

Major Investments in FY 2018: In FY 2018, 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, 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. The FY 2018 decrease will require reassessment and refocusing of priorities for support by NSF and NCAR.

Aircraft Support: NCAR operates two NSF aircraft: a C-130Q Hercules and a Gulfstream-V (the 'G-V'), 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 atmospheric, solar, 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 and solar observing platforms through its Earth Observing Laboratory (EOL) and High Altitude Observatory (HAO), including a large, deployable, dual-wavelength Doppler radar, upper atmosphere observing capabilities, an advanced coronagraph, and other experimental systems.

Research and Education Support: 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 Earth System processes;
- 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 with university colleagues are integral to NCAR's success as an institution, and NCAR serves 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 information and analysis platforms 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.

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, 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) and the Division of Acquisition and Cooperative Support (DACS), provide oversight of NCAR and the cooperative agreement under which UCAR manages NCAR. 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. UCAR submits for AGS approval an annual program plan for NCAR that details how resources will be used, and an annual report on the previous year's scientific accomplishments and achievements. UCAR also reports annually to NSF on its activities as NCAR's manager. Annual strategic planning between AGS, UCAR, and NCAR ensures that scientific and facility priorities align 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 research community. In addition, other federal agencies (such as NOA, NASA, DOD, DOE and the FAA), state authorities, and the private sector 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. No significant issues were raised in either of the most recent reviews.

Renewal/Recompetition/Termination

In 2016, AGS conducted a comprehensive review of NCAR's science programs and facilities, and UCAR's management of NCAR. The review was conducted as a series of site visits to NCAR by teams comprising members of the research community with expertise in the atmospheric and related sciences and in the management of scientific centers and facilities. The site visit teams all found that NCAR continues to be a world-leading research center, providing essential services and capabilities that foster excellence throughout the atmospheric and geospace sciences community.

The current cooperative agreement between NSF and UCAR covers the five-year period FY 2014-FY 2018. It is anticipated that the cooperative agreement for management of NCAR will be re-competed prior to the next award period, which will be for the five years beginning in FY 2019.

NATIONAL OPTICAL ASTRONOMY OBSERVATORY $20,670,000 -$1,320,000 / -6.0%

National Optical Astronomy Observatory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
$21.99	-	$20.67	-$1.32	-6.0%

The National Optical Astronomy Observatory (NOAO) was established in 1984 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, and 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 2016, 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*[20], 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.

[20] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

The PRC recommendations were implemented as of October 1, 2015. The 2.1-meter telescope is now operated by the California Institute of Technology for a research program on cosmic transient phenomena. Starting in FY 2016, the NOAO base operations and maintenance budget excluded NSF funding for the Mayall and WIYN telescopes. Any subsequent NSF support for these telescopes is recorded as special projects with supplemental funding to NOAO.

Total Obligations for NOAO

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
NOAO Base O&M	$17.61	-	$18.57	$19.13	$19.70	$20.29	$20.90	$21.53
Tucson Operations	*8.61*	-	*9.02*	*9.29*	*9.57*	*9.86*	*10.15*	*10.46*
Chilean Operations	*8.00*	-	*8.49*	*8.74*	*9.01*	*9.28*	*9.56*	*9.84*
Kitt Peak Operations	*1.00*	-	*1.06*	*1.09*	*1.12*	*1.16*	*1.19*	*1.23*
Special Projects: WIYN and Mayall	4.38	-	2.10	1.00	1.00	1.00	1.00	1.00
Total, NOAO	**$21.99**	**-**	**$20.67**	**$20.13**	**$20.70**	**$21.29**	**$21.90**	**$22.53**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreements 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 42 U.S. member institutions and five 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 do 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, visitor centers, and a web-based information portal at www.noao.edu.

NOAO Base O&M: $18.57 million, $960,000 above the FY 2016 Actual.

Tucson Operations: $9.02 million, $410,000 above the FY 2016 Actual: This covers the headquarters, offices, laboratories, and workshops in Tucson, Arizona.

Chilean Operations: $8.49 million, $490,000 above the FY 2016 Actual: This supports administration and labs in La Serena, Chile and mountain operations on Cerro Tololo and Cerro Pachón.

Kitt Peak Operations: $1.06 million, $60,000 above FY 2016 Actual: 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): $2.10 million, $2.28 million below the FY 2016 Actual.

WIYN telescope: $1.0 million, no change from the FY 2016 Actual: 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: $1.10 million, $2.28 million below the FY 2016 Actual: The decrease from FY 2016 anticipates an increase in DOE support for the telescope. In FY 2015, 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, starting in FY 2019. DESI passed the DOE Critical Decision 3 (Approve Start of Construction) milestone in FY 2016.

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 FY 2019, the fourth year of the five-year cooperative agreement.

Renewal/Competition/Termination

The last competition for management and operation of NOAO was completed with the issuance of a new cooperative agreement with AURA starting October 1, 2015 and ending September 30, 2020.

NATIONAL RADIO ASTRONOMY OBSERVATORY $76,340,000

-$5,150,000 / -6.3%

National Radio Astronomy Observatory

(Dollars in Millions)

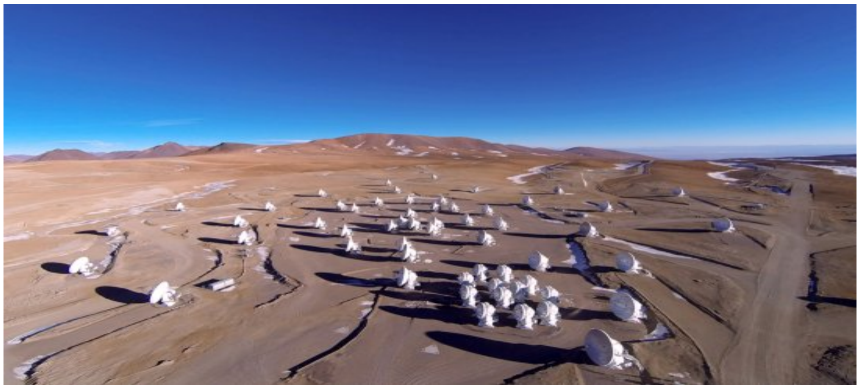
FY 2016 Actual[1]	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$81.50	-	$76.34	-5.16	-6.3%

[1] Includes $2.11 million provided by the MPS Office of Multidisciplinary Activities for expenses associated with the separation of the Green Bank Observatory and Very Long Baseline Array from NRAO and ALMA.

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.

Including the ALMA operations staff located at NRAO, staff in FY 2018 will consist of 296 full-time equivalent positions (FTEs) in the operations and maintenance components: 105 in telescope operations, 60 in science support and research, 36 in development programs, 51 in computing and data management, 25 in administrative services, and 19 in education and public outreach. These numbers exclude staff at the partitioned GBT and VLBA telescopes which will be managed and operated separately from NRAO as well as 94 staff in the NRAO common cost pool which provides services to multiple observatories. In addition, the NRAO managing



ALMA is in science operations following the completion of construction in 2015. An international partnership between North America, Europe, and East Asia, ALMA provides orders-of-magnitude improvement in observing sensitivity and image quality over previous facilities. *Credit: NRAO/AUI.*

organization, Associated Universities, Inc. (AUI), employs local ALMA operations staff in Chile, currently consisting of approximately 237 FTEs.

Total Obligations for NRAO

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	$43.84	-	$32.86	$33.95	$34.97	$36.02	$37.10	$38.22
Telescope Operations	*16.16*	-	*11.19*	*11.09*	*10.92*	*11.25*	*11.59*	*11.94*
Development	*3.30*	-	*3.37*	*3.94*	*4.56*	*4.70*	*4.84*	*4.99*
Science Operations	*4.72*	-	*6.19*	*6.40*	*6.59*	*6.79*	*6.99*	*7.20*
Administrative Services	*14.39*	-	*9.42*	*9.74*	*10.04*	*10.33*	*10.64*	*10.96*
Directors Office	*2.41*	-	*2.03*	*2.10*	*2.16*	*2.23*	*2.30*	*2.36*
Education and Public Outreach	*0.75*	-	*0.66*	*0.68*	*0.70*	*0.72*	*0.74*	*0.77*
NRAO/GBO/VLBA separation expenses	*2.11*	-	-	-	-	-	-	-
ALMA Operations	37.66	-	43.48	45.88	47.26	48.68	50.14	51.64
Total, NRAO	**$81.50**	**-**	**$76.34**	**$79.83**	**$82.23**	**$84.70**	**$87.24**	**$89.86**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2026.

The FY 2018 Budget Request for NRAO is below the FY 2016 Actual due to the partitioning of the Green Bank Observatory (GBO) and Very Long Baseline Array (VLBA) from NRAO, and because of funding carried over from the previous award which ended in FY 2016. GBO and VLBA are presented in the "Other Astronomical Facilities" narrative in the Facilities chapter of this document. Due to the favorable exchange rate and fuel prices in Chile, the FY 2016 Actual for ALMA Operations was below the FY 2016 Budget Request and the FY 2018 Budget Request is below the estimate for steady state funding.

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 2016, NRAO received approximately $2.25 million from non-AST sources at NSF, $1.70 million from other federal agencies, and $4.52 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.

Telescope operations, $11.19 million: This encompasses support for direct telescope and array operations of the VLA including maintenance, infrastructure upgrades, and telescope management.

Development, $3.37 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, $6.19 million: This area includes telescope time allocation, staff research, science training and education, and science community outreach.

Administrative services, $9.42 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, $2.03 million: This supports the director's office and managing organization costs.

Education and Public Outreach, $660,000: NRAO supports a comprehensive outreach program that makes information about radio astronomy available to the public.[21] 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.

ALMA Operations, $43.48 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 steady state operations in FY 2018. 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 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/Competition/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.

[21] https://public.nrao.edu/

NATIONAL SOLAR OBSERVATORY

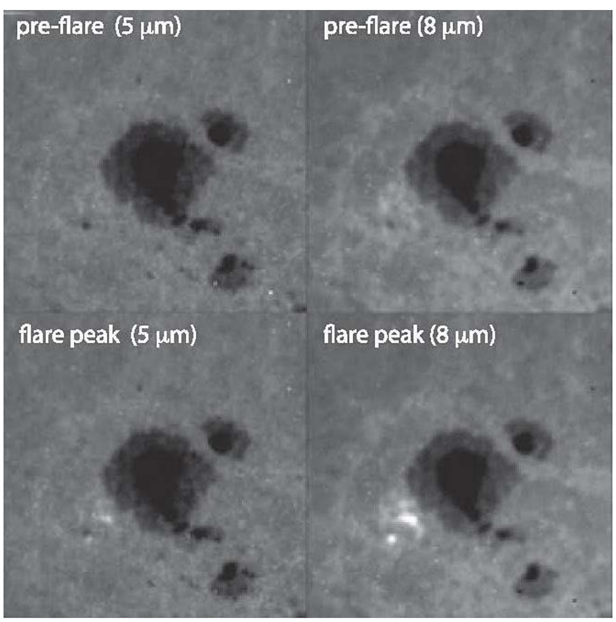
$19,000,000
-$2,000,000 / -9.5%

National Solar Observatory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Change over FY 2016 Actual Percent
$21.00	-	$19.00	-$2.00	-9.5%

The FY 2018 Budget Request for the National Solar Observatory (NSO) is $19.0 million. This is a $2.0 million (-9.5 percent) decrease from the FY 2016 Actual. FY 2018 marks the continuation of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate the Daniel K. Inouye Solar Telescope (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 late 2019-early 2020.

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 the world's largest collection of optical and infrared solar telescopes and auxiliary instrumentation available to qualified scientists to observe the solar photosphere, chromosphere, and corona. NSO 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 first simultaneous mid-infrared images at 5.2 μm *(left)* and 8.2 μm *(right)* of a solar flare. Image taken with the QWIP instrument on the McMath-Pierce solar telescope. *Credit: M. Penn, NSO.*

NSO telescopes are open to all astronomers regardless of institutional affiliation based on peer-reviewed observing proposals. In FY 2016, 32 unique observing programs from 25 U.S. and 7 foreign institutions were carried out using NSO facilities. This is a reduction from previous years as NSO ramps down its involvement in Sacramento Peak and McMath-Pierce. Students were part of 13 percent of these programs, which included three Ph.D. thesis projects. Nearly 21 terabytes of NSO synoptic data were downloaded from the NSO Digital Library. NSO employed approximately 120 staff members in FY 2016, 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,*[22] the NRC committee recommended that "NSF-Astronomy

[22] www.nap.edu/catalog.php?record_id=12951

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,*[23] 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) at Sacramento Peak through 2017 and a 50 percent reduction in funding of the NSO integrated synoptic program (NISP). The status of the divestment of NSO operated facilities is as follows:

- *McMath-Pierce solar telescope, Kitt Peak, AZ*: A university-based consortium previously expressed interest in continuing operations of the McMath-Pierce at a reduced level; however, this consortium has not materialized. NSO is in the final year of the ramp down of its participation in McMath-Pierce from $200,000 in FY 2014 to $0.0 by the end of FY 2017. NSF completed a divestment options study of NSO facilities on Kitt Peak and anticipates beginning the environmental impact statement (EIS) process in FY 2017. On March 31, 2017, NSO/AURA issued a request for proposals from parties interested in taking over operation of McMath-Pierce for scientific and educational purposes. Applicants submitted letters of intent by the May 1, 2017 deadline.
- *Sacramento Peak Observatory, Sunspot, NM*: This facility includes the DST and associated infrastructure including office space, laboratory space, dining facilities, and housing. Funding for full operations of Sacramento Peak ramps down to the end of FY 2017 at which time NSO will cease operating the facility. A proposal from New Mexico State University (NMSU) to transition operations of the facility from NSO to an NMSU-led consortium was funded in FY 2016. NSF completed a divestment options study of NSO facilities on Sacramento Peak in Q3 of FY 2016. In compliance with the National Environmental Policy Act (NEPA), NSF began preparation of an Environmental Impact Statement (EIS) in Q4 of FY 2016. The EIS is expected to be completed in FY 2018.
- *NSO Integrated Synoptic Program*: NISP consists of the Global Oscillations Network Group (GONG) and the Synoptic Optical Long-term Investigations of the Sun (SOLIS). GONG now has a component of its operations funding provided through a 5-year (FY 2016 – FY 2020) interagency agreement with the National Oceanic and Atmospheric Administration (NOAA). This NOAA funding supports the use of GONG and its data products for operational space weather forecasting (see Partnerships section below).

[23] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Total Obligations for NSO

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
NSO Base Operations	$6.75	-	$4.73	$3.70	$3.82	$3.92	$4.04	$4.16
NSO Education & Public Outreach	0.25	-	0.27	0.30	0.31	0.32	0.33	0.34
DKIST Operations[2]	11.50	-	14.00	16.50	17.01	17.54	18.08	19.13
GONG Refurbishment	2.50	-	-	-	-	-	-	-
Total, NSO	**$21.00**	**-**	**$19.00**	**$20.50**	**$21.14**	**$21.78**	**$22.45**	**$23.63**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2024.

[2] Total R&RA account funding for DKIST consists of $14.0 million in FY 2018 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.

Partnerships and Other Funding Sources: The managing organization for NSO is the Association of Universities for Research in Astronomy, Inc. (AURA), which comprises 42 U.S. member institutions and five international affiliate members. NSO partners include NOAA, 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. Industry sub-awardees in aerospace, optical fabrication, and information technology develop new telescopes, instrumentation, and sensor techniques.

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 was highlighted by the October 29, 2015 rollout of the National Space Weather Strategy[24] and the associated National Space Weather Action Plan.[25] Space weather forecasting requires both accurate models of the heliospheric environment and precise observational data inputs to those models. NSO's GONG program provides operational data products on a routine basis that are used as inputs to predictive space weather models from the U.S. Air Force and the NOAA Space Weather Prediction Center (SWPC). The FY 2016 support for NSO included a one-time $2.50 million investment in GONG to increase its robustness for future space weather predictions. NSO is in the process of upgrading the GONG facility with this funding. Also in FY 2016, NSF and NOAA signed an interagency agreement whereby NOAA is providing approximately $800,000 per year in funding support for GONG operations.

NSO Base Operations, $4.73 million, $2.02 million below the FY 2016 Actual: NSO Base Operations includes the offices at NSO's Boulder, CO headquarters 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. By the end of FY 2017, NSO expects to be disengaged from operations at Sacramento Peak Observatory in Sunspot, New Mexico and from the McMath-Pierce and Vacuum Tower facilities based on Kitt Peak, Arizona. The funding profile for NSO Base Operations has been ramping down in anticipation of the divestment of these redundant facilities by the end of 2017. Beginning in FY 2019, NSO Base Operations will fund NSO Directorate activities and operations of the synoptic program at a steady-state level of about $4.0 million ($2.0 million each) per year.

DKIST Operations, $14.0 million, $2.5 million above the FY 2016 Actual: 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 2018 Budget Request for DKIST Operations represents the fourth year of a five-year funding ramp that will bring the NSO budget to a level commensurate with requirements to operate DKIST. This profile is

[24] www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf

[25] www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatheractionplan_20151028.pdf

funding the development of the DKIST science operations and data center in preparation for full DKIST operations, which is expected to begin late 2019-early 2020.

Education and Public Outreach, $270,000, $20,000 above the FY 2016 Actual: 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 portal at www.nso.edu.

In preparation for the total solar eclipse in August 2017, and with the imminent arrival of DKIST, NSO significantly increased its efforts in education, public outreach, and broadening participation by establishing an Office of Education and Outreach (OEO). In FY 2016, NSO hired a new office head and recently filled a second EPO position, based in Maui, focused on DKIST.

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. In February 2017, NSF held a review of NSO's Annual Progress Report and Program Plan (APRPP). From December 2015 through March 2016, NSF conducted a Business Systems Review (BSR) covering AURA and NSO. Findings and recommendations from the final NSF report were conveyed to AURA on April 1, 2016, and AURA continues to resolve issues and implement recommendations from the report. NSO also participated in reviews of the DKIST project in FY 2016 including: a contingency assessment (Feb. – July 2016) and an Earned Value Management System validation review (Sept. 2016), both of which are described in the DKIST narrative in the MREFC chapter.

Renewal/Competition/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. Because of additional time required to implement the new agreement, the previous cooperative agreement was extended through May 31, 2015. The renewed cooperative agreement between NSF and AURA was put into place June 1, 2015.

OTHER ASTRONOMICAL FACILITIES $11,850,000 +$11,850,000 / NA%

Other Astronomomical Facilities

(Dollars in Millions)

FY 2016[1] Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
-	-	$11.85	$11.85	N/A

[1] Beginning in October 2016, funding for these facilities as stand-alone entities is provided separately from National Radio Astronomy Observatory (NRAO).

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). Beginning in FY 2017, GBO and the VLBA were separated from NRAO. GBO now operates the GBT, and the newly formed Long Baseline Observatory (LBO) operates the VLBA. Associated Universities, Inc. (AUI), remains the managing organization for GBO and LBO through a cooperative agreement with NSF. This narrative presents the combined FY 2018 Budget Request for GBO and LBO.

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,*[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 (AST) in the Directorate for Mathematical and Physical Sciences (MPS) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee 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.

In 2012, the Portfolio Review Committee recommended, under constrained budgets, 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,[28] NSF partitioned GBT and VLBA from the competition for NRAO management and operations, which increased 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 produced feasibility reports for divestment alternatives of both GBO and VLBA; those reports include baseline structural and environmental surveys of GBO and VLBA. In FY 2017, NSF began a formal environmental review of GBO to develop an Environmental Impact Statement (EIS) considering future alternatives for GBO, and the EIS process is expected to conclude in FY 2018.

In FY 2016, AST received a proposal from AUI, to continue management and operation of GBO and LBO in FY 2017 and FY 2018, separate from the management and operation of NRAO. Previously, the

[26] www.nap.edu/catalog.php?record_id=12951
[27] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[28] http://nsf.gov/pubs/2013/nsf13074/nsf13074.jsp

obligations for GBO and VLBA were heavily matrixed and not separable from the overall obligation for NRAO. Hence, GBO and VLBA, which were previously included in the NRAO narrative, were first presented as stand-alone entities in the FY 2017 Budget Request. The table below does not separate funding for GBO and LBO, and the detailed breakdown between the two depends 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 Other Astronomical Facilities

(Dollars in Millions)

	FY 2016 Actual[1]	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[2] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance	-	-	$11.85	$11.85	$11.85	$11.85	$11.85	$11.85

[1] Beginning in October 2016 (FY 2017), funding for these facilities as stand-alone entities is provided separately from National Radio Astronomy Observatory (NRAO) funding.

[2] Outyear funding estimates are for planning purposes only. The operating award for GBO and LBO is expected to run through the end of September 2018.

Partnerships and Other Funding Sources: In FY 2018, GBO and LBO are expected to receive approximately $8.60 million from other sources, roughly half from non-federal partners and half from other federal sources. Thus, the FY 2018 Budget Request represents about 58 percent of the total budget for GBO and LBO. Many of these partnerships involve guaranteed allocations of observing time on the GBT or VLBA. In FY 2016, GBO began a 10-year partnership with Breakthrough Listen and also had funding partnerships with West Virginia University and the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) consortium that are expected to continue through FY 2018. (The NANOGrav funding comes from the NSF award to the NANOGrav Physics Frontier Center.) In addition, the GBO partnership with the RadioAstron space mission is continuing in FY 2017, and other partner discussions are ongoing. In FY 2017, NSF and LBO established an agreement with the U.S. Naval Observatory to provide observing time and data in exchange for substantial support of LBO/VLBA operations.

Education and Public Outreach: The Green Bank Science Center at GBO currently supports nearly 50,000 visitors per year and carries out dedicated programs for professional educators and school groups.

GBO and LBO Operations and Maintenance, $11.85 million: This encompasses support for direct telescope operations at GBO and LBO, including maintenance, infrastructure upgrades, and telescope management, as well as funds allocated for 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 LBO 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. 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 observatories through its own community-based oversight and users committees. The GBO and LBO directors report directly to the AUI Vice President for Radio Astronomy.
- Reviews: NSF reviewed the proposal for FY 2017 and FY 2018 funding and conducts annual reviews of the Program Operating Plan and reports.

Renewal/Competition/Termination

GBO and LBO are currently supported through a cooperative agreement, which ends on September 30, 2018. A six-month transition award in FY 2016 provided for implementation costs of separating GBO and LBO from NRAO (see the NRAO narrative for more details), and the FY 2018 funding provides for GBO and LBO as stand-alone entities. Management of GBO and LBO after FY 2018 will be based on the further development of collaboration opportunities and the EIS process mentioned 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 major 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

Major FY 2018 Investments:

Cyber-enabled Materials, Manufacturing, and Smart Systems.............. NSF-Wide Investments - 3

Innovations at the Nexus of Food, Energy, and Water Systems............ NSF-Wide Investments - 5

NSF Innovation Corps .... NSF-Wide Investments - 7

Risk and Resilience.. NSF-Wide Investments - 9

Secure and Trustworthy Cyberspace .... NSF-Wide Investments - 11

Understanding the Brain .... NSF-Wide Investments - 13

STEM Education and Workforce:

Improving Undergraduate STEM Education .... NSF-Wide Investments - 15

Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science.. NSF-Wide Investments - 19

Major Investments in Science, Technology, Engineering, and Mathematics (STEM) Graduate Students and Graduate Education.. NSF-Wide Investments - 21

Other NSF-Wide Activities:

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Selected Crosscutting Programs .... NSF-Wide Investments - 31

NSTC Activities

National Nanotechnology Initiative.. NSF-Wide Investments - 33

Networking and Information Technology R&D.....................................NSF-Wide Investments - 38

U.S. Global Change Research Program.. NSF-Wide Investments - 42

CYBER-ENABLED MATERIALS, MANUFACTURING, AND SMART SYSTEMS (CEMMSS) $219,100,000 -$52,420,000 / -19.3%

Overview

The Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) framework integrates a number of science and engineering activities across NSF–breakthrough materials, advanced manufacturing, and smart systems, including robotic and cyber-physical systems. Through CEMMSS-funded research, materials with unique properties and functionality are being discovered and developed more reliably and efficiently through the integration of theory, simulation, data analytics, and experiments. Further, using advanced manufacturing strategies, new materials are being fashioned into objects, structures, and systems embedded with computational intelligence, thereby transforming static systems, processes, and edifices into adaptive, pervasive smart systems. Ultimately, CEMMSS is leading to fundamental scientific advances in intelligent, autonomous physical systems that can operate successfully and collaboratively in dynamic, uncertain, and unanticipated environments.

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. The systems will collaborate with humans and with one another. These advances have the potential to accelerate scientific discoveries to address key national and societal challenges critical to U.S. security and competitiveness.

CEMMSS is a six-year investment area, spanning FY 2013-FY 2018. While the NSF-wide CEMMSS investment will conclude at the end of FY 2018, collaborative research activities pursued under CEMMSS are expected to continue.

CEMMSS comprises a research portfolio and enables new multidisciplinary research communities in the following three grand challenge areas:

- *Breakthrough Materials* investments accelerate the discovery and development of materials required for meeting societal needs and finding paths for sustainable and scalable manufacturing technologies;
- *Advanced Manufacturing* investments advance knowledge for production of novel products through processes that depend upon the coordination of information, computation, automation, networking, or other emerging scientific capabilities; and
- *Smart Systems* investments drive next-generation robotics and cyber-physical systems, with enhanced adaptability, functionality, reliability, safety, and usability in dynamic and unanticipated environments.

By the end of CEMMSS, there will be evidence of an integrated and thriving ecosystem of cyber-enabled systems composed of advanced materials; improved interdisciplinary education; and research infrastructure used by CEMMSS scientists and engineers.

Goals

The following three goals have been established to realize significant advances in the aforementioned grand challenge areas:

- Goal 1: Science and Engineering
  CEMMSS is establishing a scientific basis, a codified knowledge base, and shared principles for leveraging advanced materials, and designing, manufacturing, and deploying cyber-enabled smart systems.
- 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 the development of a vibrant and capable workforce to ensure a pipeline of talent and a growing community in these critical areas.

- Goal 3: Research Infrastructure
  CEMMSS is developing the critical research infrastructure that can be used to discover, test, refine, and validate the advanced materials, along with the design, manufacturing, and development methods that enable the deployment of smart systems.

FY 2018 Investments

Goal 1: Science and Engineering

- Advanced Manufacturing: NSF will continue to invest in Scalable Nanomanufacturing and Cellular Biomanufacturing, leveraging tools from engineering and biology (including synthetic biology), as well as in cyber-manufacturing systems.
- Breakthrough Materials: NSF will focus on strengthening existing projects by supporting the development of intra- and inter-project connections. Supplements to existing awards will be used to identify synergies within the research community and to accelerate pathways for transitioning innovative materials to practice.
- Smart Systems: NSF will refine the Cyber-Physical Systems (CPS) and National Robotics Initiative (NRI) program solicitations to include emphases on autonomous, intelligent systems. Additionally, NSF will examine the social, behavioral, and economic research issues associated with the design, manufacturing, and deployment of Smart Systems.

Goal 2: Education, Workforce Development, and Community Building

NSF will continue to support and facilitate partnerships with other federal agencies, industry, professional societies, and other stakeholders to build a robust research portfolio, accelerate the transition of research to practice, and hone educational and workforce development opportunities. Partnerships have proven valuable in facilitating a diverse, use-inspired CEMMSS research portfolio, for example, the CPS program, which comprises five federal agencies in addition to NSF; industry partners facilitating the Transition to Practice award option; and a recent National Academies' study on the future of CPS education.

Goal 3: Research Infrastructure Development

NSF will support data, software, and physical infrastructure necessary for CEMMSS. Specifically, for Breakthrough Materials, NSF will continue investments in the two Materials Innovation Platforms focused on two-dimensional materials. For Smart Systems, NSF will emphasize engaging the relevant community to identify infrastructure requirements and incentives for community adoption and use of such infrastructure.

Cyber-Enabled Materials, Manufacturing, and Smart Systems
Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$5.48	-	$5.48
CISE	91.93	-	72.70
ENG	110.00	-	101.25
MPS	63.83	-	39.67
SBE	0.28	-	-
Total, CEMMSS	**$271.52**	**-**	**$219.10**

INNOVATIONS AT THE NEXUS OF FOOD, ENERGY, AND WATER (INFEWS) $24,400,000 -$55,700,000 / -69.5%

Overview

Humanity is reliant upon the natural and physical systems of the Earth for provision of food, energy, and water (FEW) resources. With world population projected to increase to nine billion (U.S. population reaching 400 million) by 2050 and urban populations expected to double, there are expected to be major increases in demand for these resources. The Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) investment area enables interagency cooperation on one of the most pressing problems of the millennium—understanding interactions across the FEW nexus, how it is likely to affect our world, and how we can proactively plan for its consequences.

Food, energy, and water systems interconnect and are interdependent in many ways. Water is required for the production of energy—hydropower, cooling of electric power plants, energy production, etc. Energy is needed for wastewater treatment, desalination, pumping groundwater, and for transport of water. Water and energy are critical for agriculture and food production. Biofuels consume water and, in some instances, result in reductions in the production of food. In addition, different land use practices, increased urbanization, and climate variability have major impacts on all three. 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 the social, behavioral, and economic decisions made by individuals, organizations, and governments. Given the increased demand on these resources, societies can no longer sustain optimal operation for one system (i.e., food, energy, or water system), we must plan our interaction within the FEW system of systems so that no system fails even if it means that all systems operate sub-optimally.

The food, energy, and water nexus creates a grand research challenge: to understand how these complex, coupled processes and systems function now and in the future. There is also a critical need for research to enable new technologies that will enhance the productivity of the system and subsystems, maximize efficient overall usage of FEW resources, and define new means for socially and technologically adapting to future variability and demands. Investigations of this complex system will produce discoveries that cannot emerge from research on food or energy or water systems alone; the interactions among these components and the context(s) of the problem(s) they pose at the FEW nexus will produce new knowledge and technologies. NSF support of basic research in the science and engineering disciplines is needed to understand the interdependent and interconnected FEW systems and could lead to an integrated model useful not only for scientific understanding, but also informed decision-making.

INFEWS investments began in FY 2016 and are planned to continue through FY 2020. The overarching goal is to improve understanding of the interdependencies of the FEW systems, within a disciplinary and interdisciplinary context. Examples include:

- Improve understanding of FEW systems embedded in differing social contexts and the societal vulnerabilities of these systems with respect to short and long timescale events (e.g., weather, power outages, resource distribution, population pressures, and land-use changes).
- Advance scientific and engineering understanding to:
  - Improve systems models covering a range of environments, technologies, policies, individual and organizational behaviors, and relative weighting of FEW stresses/needs across the scope of the human, built, and natural environments;
  - Enable discoveries that lead to technological innovations incorporating sustainability, safety, security, efficiency, and affordability, while addressing relevant social, economic, and cultural factors; systems or models that promote efficient use of resources, as well as conversion and/or reuse of waste materials;

- Inform technologies and policies that improve food security and agricultural practices that better maintain ecosystem services;
- Strengthen partnerships with projects at the state and local levels that will test research results in real-world systems; and
- Encourage the results of modelling as well as technological and social solutions to be widely available to agencies, industries, and the public through computing interfaces that encourage interaction, contribution of additional data, and local application.

Goals

- Goal 1: Significantly advance our understanding of the food-energy-water system through quantitative and computational modeling, including support for advanced cyberinfrastructure;
- Goal 2: Develop real-time, cyber-enabled interfaces that improve understanding of the behavior of FEW systems and increase decision support capability;
- Goal 3: Enable research that will lead to innovative solutions to critical FEW system problems; and
- Goal 4: Grow the scientific workforce capable of studying and managing the FEW system, through education and other professional development opportunities.

FY 2018 Investments

In FY 2018, solicitations will emphasize: computational FEW system modeling ($11.95 million), innovative system solutions ($7.45 million), and contributing activities ($5.0 million).

Projects are significantly advancing scientific and engineering understanding and modeling of the complex FEW system and water-energy, food-energy, and food-water subsystems, as well as their interdependencies under multiple conditions. In partnership with the U.S. Department of Agriculture, projects integrate expertise from agricultural, computational, ecological, economic, energy, engineering, hydrological, mathematical, and social areas to enable technological innovations that improve security and affordability.

In FY 2018, fundamental scientific and engineering research will focus on systems models that cover a range of climates and organizational behaviors across built and natural environments. Emphasis will be placed on new design concepts and technologies that promote efficient use of resources and improve food security and agricultural practices that better maintain ecosystem services. Contributions will also be made to relevant graduate education experiences and to advanced phenotyping and microbiome technologies that have potential to translate into improved agricultural productivity and efficient use of resources such as land, water, nitrogen, and phosphorous.

Innovations at the Nexus of Food, Energy, and Water Systems
Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$7.50	-	-
CISE	8.00	-	-
EHR	8.81	-	3.00
ENG	9.84	-	5.00
GEO	5.00	-	8.00
MPS	5.02	-	-
SBE	4.50	-	2.50
IA	30.24	-	5.00
OISE	1.20	-	0.90
Total, INFEWS	**$80.10**	**-**	**$24.40**

NSF INNOVATION CORPS (I-CORPS™) $26,150,000

-$3,590,000 / -12.1%

Overview

The National Science Foundation Innovation Corps (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) composed of I-Corps™ Nodes and I-Corps™ Sites that work cooperatively to build, utilize, and sustain the national innovation ecosystem. I-Corps™ Nodes support innovation research and education, and enhance the development of technologies, products, and processes that benefit society. The interconnected Nodes of this network are diverse in research areas, resources, tools, programs, capabilities and geographic locations; the network has the flexibility to grow and reconfigure as needs evolve. The I-Corps™ Sites catalyze local teams to explore the transition of their technology concepts into the marketplace. The Sites also offer infrastructure, resources and networking opportunities that serve the teams, while developing the local innovation ecosystem. These components all contribute to enhancing and enlarging the national network of mentors, researchers, entrepreneurs and investors.

Goals

NSF established the I-Corps™ program in FY 2011 to cultivate a national innovation ecosystem that builds upon fundamental research advances and accelerates the translation of scientific research towards the development of technologies, products, and processes that benefit society. 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 technology-based innovation and entrepreneurship, and to help fulfill the promise of their discoveries;
- Foster national collaborations of academic researchers with peers conducting research commercialization, industrial mentors, startup investors, and entrepreneurial educators; 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.

FY 2018 Investments

I-Corps™ Team awards support NSF-funded researchers who are interested in transitioning their research out of the lab. I-Corps™ Teams are given access to immersive experiential entrepreneurial education together with 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 the business model tested during I-Corps; (2) substantial first-hand evidence for or against product-market fit, with a pithy definition of the customer segments and corresponding value propositions; and (3) a narrative of a compelling technology demonstration for potential partners. As of April 2017, 954 Teams have undertaken the curriculum. Approximately 45 percent of these Teams have started their own companies, and three 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.

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. The I-Corps™ Nodes and Sites have created a national startup incubator called the National Innovation Network (NIN), which provides academic researchers with ever-evolving resources for academic spin-outs.

Specific investments

The I-Corps™ NIN leverages existing entrepreneurial and innovation capacities in universities and taps into federal, state, and regional resources; it offers significant potential to reach out to a large number of budding and existing innovators and entrepreneurs. In FY 2018, NSF will continue to scale-up the I-Corps™ program by increasing the numbers of I-Corps™ Nodes nationwide to reach a steady state of ten nodes. NSF will also continue to build partnerships with other stakeholders who have access to innovators and entrepreneurs, including federal agencies, state governments, universities, and non-profit organizations.

Investment 1: I-Corps™ Teams

Expected outputs/milestones: Approximately 230 Teams will be supported.

Investment 2: I-Corps™ Sites

Expected outputs/milestones: A steady state of approximately 70 total active Sites, with 25 new or renewal Sites funded in FY 2018, will be maintained.

Investment 3: I-Corps™ Nodes

Expected outputs/milestones: Nine to ten active Nodes will be funded, with up to one new Node or a renewal Node funded in FY 2018.

NSF Innovation Corps
Funding by Directorate
(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$1.00	-	$1.00
CISE	11.71	-	9.65
EHR	1.55	-	-
ENG	13.08	-	13.00
GEO	0.30	-	0.30
MPS	1.60	-	1.70
SBE	0.50	-	0.50
Total, I-Corps™	**$29.74**	**-**	**$26.15**

RISK AND RESILIENCE $31,150,000

-$11,790,000 / -27.5%

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, air), energy (electricity, gas, oil, renewable), water, communications and networks (wireless and wired, including the internet), banking and finance, and many other components. The increased penetration and use of modern technologies have improved our Nation's productivity and quality of life. These technologies are now becoming deeply embedded into our society via wireless and wired networks, smart phones, and other edge devices, embedded systems, sensors, and social networks. As a result, the availability of real-time information about the state of these complex cyber-physical infrastructure systems 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, hurricanes, storms, earthquakes, and space weather and (b) man-made events such as terrorist attacks and human errors. There are indications that extreme weather events may become more frequent in the future, which highlights the importance of quantifying the potential impacts.

Through the Risk and Resilience investment area, NSF aims to improve predictability and risk assessment and to increase resilience that will reduce the impact of extreme events on our lives, society, and the economy. NSF is uniquely positioned to support such advancements, as they require multidisciplinary expertise in science, engineering, social and behavioral sciences, and education.

The Risk and Resilience investment began in FY 2016 and is planned to continue through FY 2019.

Anticipated broad outcomes at the end of this initiative include:

- A comprehensive and integrated risk and resilience knowledge base useful for informed decision-making and risk mitigation;
- New, synthesized approaches that will improve resilience, interoperations, performance, and readiness in Interdependent Critical Infrastructures (ICIs), and;
- Advanced understanding of the organizational, social, psychological, legal, political, and economic obstacles to improving ICIs, the strategies for overcoming these obstacles and the role of these advances in the context of increasingly smart and connected communities.

Goals

- Goal 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. This goal is supported by a focused research effort, Prediction of and Resilience against Extreme Events (PREEVENTS), that will help us to better understand and mitigate the risks posed to the U.S. by natural hazards.

- Goal 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. This goal is supported by the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) program.

FY 2018 Investments

In FY 2018, PREEVENTS, at $17.75 million, and CRISP, at $12.90 million, will continue, as will some contributing activities, at $500,000.

In the PREEVENTS program, awards have focused on earthquakes, sinkholes, volcanic activity, plate boundaries, tsunamis and tropical cyclones. Workshops have fostered community expansion on relevant but underdeveloped disciplinary and cross-disciplinary problems. Research Coordination Networks (RCNs) supported in FY 2017 have enabled groups of investigators to share information and ideas; coordinate research activities; foster synthesis and new collaborations; develop community standards; and advance science and education through communication and sharing of ideas across disciplinary, organizational, geographic, and international boundaries. These new networks are increasing understanding of current risk and resilience issues and knowledge gaps, thus informing FY 2018 solicitations. Going forward, emphasis will be placed on synthesis of results and identifying areas for needed research and improving dissemination of information to end-users.

CRISP projects supported new research on topics that included interdependent energy and water systems, decision making in emergency healthcare response systems, and resilience of financial infrastructures in response to extreme events. CRISP projects planned for FY 2017 will catalyze collaborations among researchers across the domains of engineering, computer and computational science, and the social/behavioral/economic sciences. These awards will create theoretical frameworks and multi-disciplinary models of ICIs, including in the context of smart and connected communities to inform future investments. In FY 2018, the CRISP program will promote research on ICI systems and processes and educate the next generation of scientists and engineers be able to improve the resilience of our infrastructures in the face of changing and increasing risks. The projects supported will make ICI services more effective, efficient, dependable, adaptable, resilient, safe, and secure, taking into account the human systems in which they are embedded.

In addition, $500,000 for contributing activities includes two interagency activities, one with the Department of Energy on the modern power grid and the other with the National Geospatial Intelligence Agency (NGA) developing algorithms for analyzing large datasets.

Risk and Resilience
Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
CISE	$5.98	-	-
ENG	12.00	-	10.00
GEO	16.75	-	17.25
MPS	2.31	-	0.50
SBE	4.90	-	2.90
OPP	1.00	-	0.50
Total, Risk and Resilience	**$42.94**	**-**	**$31.15**

SECURE AND TRUSTWORTHY CYBERSPACE (SATC) $113,750,000

-$16,030,000 / -12.3%

Overview

In today's increasingly networked, distributed, and asynchronous world, cybersecurity involves hardware, software, networks, data, people, and integration with the physical world. Society's overwhelming reliance on this complex cyberspace has, however, exposed its fragility and vulnerabilities as corporations, agencies, national infrastructure, and individuals have been victims of cyber-attacks. Achieving a truly secure cyberspace requires addressing not only challenging scientific and engineering problems involving many components of a system but also vulnerabilities that arise from human behaviors and choices. Examining the fundamentals of security and privacy as a multidisciplinary subject can lead to fundamentally new ways to design, build, and operate cyber systems; protect existing and future infrastructure; and motivate and educate individuals about cybersecurity. This requires expertise across computer science; engineering; statistics; mathematics; the social, behavioral, and economics sciences; and education, as well as the transition of new concepts and technologies into practice.

Secure and Trustworthy Cyberspace (SaTC) is a seven-year investment area, spanning FY 2014-FY 2020. However, NSF's emphasis on cybersecurity research is expected to continue beyond FY 2020 because it constitutes an enduring challenge for science and engineering research and education that must evolve constantly to address new threats.

Outcomes from SaTC will include development of an organized, cohesive scientific foundation for the body of knowledge that informs the field of cybersecurity and privacy; improved understanding of the root causes of current threats; development of foundational countermeasures, including approaches that leverage designed-in security, moving target defense, tailored trustworthy spaces, and cyber-economic and behavioral incentives; and the establishment of recommendations for new instructional materials, degree programs, and educational pathways. In particular, foundational research in SaTC will lead to a research community pursuing a broad and deep multidisciplinary research portfolio spanning cybersecurity and privacy, whose results underlie methods for secure critical infrastructure. Ultimately, through SaTC, NSF expects to produce an innovation ecosystem that ensures new and existing technologies are secure from attack and users' information is protected from violations of privacy despite the new attack surfaces these technologies present. Similarly, the creation of a workforce and citizenry with an understanding of cybersecurity and privacy issues is an anticipated impact of NSF's support of activities related to the education and training of cybersecurity researchers and professionals.

Goals

- Goal 1: Foundational Research
  Develop the scientific theory, methodologies, and tools necessary to the development of trustworthy and usably secure systems and appropriate privacy safeguards.
- Goal 2: Accelerating Transition to Practice
  Transition successful basic research results and commercial innovations into early adoption and use, 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.
- Goal 3: Education and Preparation of Cybersecurity Researchers and Professionals
  Increase the number of qualified students entering the fields of information assurance and cybersecurity, and enhance the capacity of higher education to produce professionals in these fields to meet the needs of our increasingly technological society. This includes NSF's investment in the CyberCorps®: Scholarship for Service (SfS) program, which supports cybersecurity education and workforce development.

FY 2018 Investments

Goal 1: Foundational Research

- Refine the SaTC program solicitation in FY 2018, including a request for Frontier projects, which are center-scale, multi-disciplinary, multi-organizational projects that provide high-level visibility to grand challenge research areas in cybersecurity.
- Fund innovative projects that advance the science of cybersecurity and privacy, as well as security for big data analytics, cloud computing, and cyber-physical systems. NSF will also support cutting-edge cybersecurity and privacy topics, including redefining cyber forensics, data science for security, privacy-aware big data management and mining, ethics for trustworthy cyberspace, theory and science for obfuscation, and information-oriented security.
- Build upon existing partnerships with other federal agencies, industry, and international organizations to more effectively achieve the long-term goals related to SaTC.
- Pursue efforts to grow the cybersecurity research community to include more researchers who cross the boundaries between computer science; engineering; statistics; mathematics; and the social, behavioral, and economic sciences.

Goal 2: Accelerating Transition to Practice (TTP)

- Focus on transitioning to practice the research results that are ready for experimental deployment, early adoption, commercial innovation, or implementation in cyberinfrastructure through support of TTP projects.
- Support at least one experimental testbed to enable cybersecurity researchers to experiment in realistic environments.

Goal 3: Education and Preparation of Cybersecurity Researchers and Professionals

- 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 existing computer science instruction; quantitative and scientific literacy curricula; and science and engineering programs for undergraduate and graduate students (e.g. SfS) who will need basic understandings of cybersecurity relevant to their domains.
- 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 students, low-income students, and veterans.

Secure and Trustworthy Cyberspace
Funding by Directorate
(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
CISE	$70.90	-	$65.50
EHR	49.98	-	40.00
ENG	3.25	-	3.25
MPS	1.64	-	1.00
SBE	4.00	-	4.00
Total, SaTC	**$129.78**	**-**	**$113.75**

UNDERSTANDING THE BRAIN (UTB) $134,460,000

-$38,290,000 / -22.2%

Overview

Understanding the Brain (UtB) is one of the grand scientific challenges at the intersection of the physical, life, behavioral, computing, and engineering sciences. In FY 2013, the multi-agency Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative was announced, with NSF as one of the lead participating agencies. Congress reaffirmed its support for NSF's continued investments in the BRAIN Initiative as part of the recent American Innovation and Competitiveness Act (PL 114-329)[1]. Through several new programs and numerous core programs across the directorates, NSF will continue to support catalytic innovation in neuroscience as well as large-scale dissemination efforts to establish a national research infrastructure that will accelerate our understanding of brain function.

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 brain, behavior, and environment interact, 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. The ultimate goal of such research is establishment of integrative, quantitative, formal, computational, and predictive theories of brain structure, activity, and function.

NSF is uniquely positioned to address this challenge and continue advancing 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. Since FY 2014, the UtB activity has consolidated NSF's ongoing activities in cognitive science, neuroscience and the BRAIN Initiative. NSF has been instrumental in supporting transformative breakthroughs in brain research and related technologies, such as optogenetics, the CLARITY brain preservation technique, and the first Food and Drug Administration (FDA) approved artificial retina, which all began with NSF support. The co-mingling of NSF's disciplinary and interdisciplinary fields is expected to foster new and convergent approaches to transform understanding of brain, cognition, behavior, and education approaches, through the development of new technologies, theories, and fundamental research. The UtB activity will continue through FY 2020.

Goals

The overall goal of UtB is to enable scientific understanding of the full complexity and function of the brain in action and in context. This multi-year goal is being pursued across four ongoing priority areas:

1. Develop innovative neurotechnologies, new tools, experimental approaches, theories, and models to monitor and analyze brain activity and integrate neuroscience information across scales and scientific disciplines.
2. Identify the fundamental relationships among neural architecture, activity, cognition, and behavior.
3. Transform our understanding of how the brain responds and adapts to changing environments and recovers from lost functionality.
4. Train a new generation of scientists, engineers, and educators for a transdisciplinary, globally competitive workforce in neuroscience and neuroengineering.

FY 2018 Investments

In FY 2018, NSF total investment in the UtB activity is $134.46 million. Within this amount, $70.52 million will support activities related to the BRAIN Initiative. NSF will maintain the UtB focus by continuing to

[1] American Innovation and Competitiveness Act (PL 114-329), SEC. 117. Retrieved from www.congress.gov/bill/114th-congress/senate-bill/3084/text

employ investment strategies designed to enable the transformational research, engineering, infrastructure development, and training required to accomplish the multi-year overall goal specified above. Using existing mechanisms including targeted solicitations, workshops, Dear Colleague Letters (DCLs), Research Coordination Networks, and special mechanisms such as EAGERs and Ideas Labs, NSF will continue to bring together the 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.

As part of the BRAIN Initiative, NSF will continue to run three distinct programs:

1. Collaborative Research in Computational Neuroscience (CRCNS): a cross-directorate, cross-agency (both NSF and the National Institutes of Health), and multinational (Germany, France, and Israel) program that funds projects with the goal of providing a powerful modality for larger-scale interaction and collaborative discovery;
2. Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS): a program that supports research and innovation to enable large-scale aggregation, sharing, and open science driven by integrative neural and cognitive discovery; and
3. Next Generation Networks for Neuroscience (NeuroNex): a program that supports "Neurotechnology Hubs" and "Theory Teams" to develop and disseminate the newest technologies and theories, respectively, to neuroscience researchers most able to capitalize on them for advancing our understanding of brain function.

Through these three programs and numerous other disciplinary and special programs across the directorates, NSF is implementing a phased approach for establishing a national research infrastructure for neuroscience. This is described in NSF's DCL "National Brain Observatory: A Phased Approach for Developing a National Research Infrastructure for Neuroscience" (NSF 16-047)[2].

Understanding the Brain
Funding by Directorate
(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$33.51	-	$46.00
CISE	30.60	-	22.15
EHR	11.00	-	9.00
ENG	18.00	-	16.75
MPS	24.13	-	16.56
SBE	26.91	-	24.00
IA	24.00	-	-
OISE	4.60	-	-
Total, UtB	**$172.75**	**-**	**$134.46**
BRAIN	*$76.53*	-	*$70.52*

[2] NSF. (2016). National Brain Observatory: A Phased Approach for Developing a National Research Infrastructure for Neuroscience (NSF 16-047) [DCL]. Retrieved from www.nsf.gov/pubs/2016/nsf16047/nsf16047.jsp

IMPROVING UNDERGRADUATE STEM EDUCATION (IUSE) — $96,500,000 / -$8,270,000 / -7.9%

Overview

Improving Undergraduate STEM Education (IUSE) underpins the agency's commitment to the highest caliber undergraduate science, technology, engineering, and mathematics (STEM) education through a Foundation-wide framework of investments. By improving the quality and effectiveness of the education of undergraduates in all STEM fields, these investments enable NSF to lead progress nationally toward a diverse and innovative workforce and a STEM-literate public. As the National Science Board (NSB) has observed: "The 'STEM workforce' is extensive and critical to innovation and competitiveness." Furthermore, the NSB writes, "Assessing, enabling, and strengthening workforce pathways is essential to the mutually reinforcing goals of individual and national prosperity and competitiveness.[3]"

Through the IUSE framework, which began in FY 2015, NSF coordinates its investments in undergraduates and undergraduate STEM education to enhance coherence and impact and to use shared metrics and evaluation approaches where appropriate. These investments address both general trends and specific disciplinary needs. Examples of general trends include the use of active learning approaches in undergraduate instruction,[4] the increase of undergraduate research courses, and attention to undergraduate degree completion. Examples of disciplinary imperatives include the need to recruit more women and minorities into majors in computer science, the importance of ensuring high-quality learning outcomes in introductory mathematics courses, the re-envisioning of introductory courses in the biological sciences in light of new research findings and theories, and the data science preparation of undergraduates in virtually all STEM disciplines. Moreover, new interdisciplinary challenges demand attention as automation and behavioral science—augmented by big data—revolutionize the workplace, the nature of work, and research practices.

Key reports and documents[5,6] contain persuasive arguments that a high-quality undergraduate experience is vital to preparing a diverse professional STEM workforce equipped to lead innovation, to growing a larger pool of STEM-savvy workers capable of employing STEM skills in business and industry, and to ensuring a STEM-literate public ready to support and benefit from the progress of science. NSF, with its mission to advance science, engineering, and education, plans to invest $96.50 million in FY 2018 through coordinated investments both across and within directorates, aligned with a coherent framework for improving undergraduate STEM teaching and learning.

Total Funding for IUSE
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
$104.77	-	$96.50

[3] National Science Board. (2015). *Revisiting the STEM workforce.* Arlington, VA: National Science Board. Retrieved from www.nsf.gov/nsb/publications/2015/nsb201510.pdf

[4] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science. *Proceedings of the National Academy of Sciences*. 111, 8410-8415. Retrieved from www.pnas.org/content/111/23/8410.abstract

[5] 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.* Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

[6] 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.

Goals

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 STEM instruction (in all NSF-supported disciplines) that leads to improved student learning and fosters widespread use of evidence-based resources and pedagogies in undergraduate STEM education.
- **Broaden participation and institutional capacity for STEM learning.** Increase the number and diversity of undergraduate students recruited and retained in STEM fields and career pathways by implementing evidence-based successful 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 inform decision-making about strategic investments to achieve the three IUSE goals.

- 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 centered on addressing the greatest challenges in U.S. undergraduate STEM education.
- The IUSE portfolio represents coordination among all NSF directorates, while respecting distinct disciplinary opportunities, challenges, and needs.
- IUSE is informed by input from multiple sources, including 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 eventually accommodate all NSF investments in undergraduate education and will be aligned with agreed-upon, corresponding directorate goals.[7]

Investment Framework

The IUSE framework uses findings from research and evaluation on STEM learning and education to address challenges common across 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 of undergraduate STEM education across a diversity of institutional types. NSF IUSE-affiliated programs are positioned to connect to and benefit from the core activities. The framework draws upon a knowledge base accumulated from decades of research, development, and best practices in STEM undergraduate education.[8,9,10,11] 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. This will generate new knowledge about learning, teaching, and implementation and how to improve the undergraduate preparation of a diverse STEM workforce.

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[7] 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 2014-16 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.

[8] National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: National Academies Press. Retrieved from www.nap.edu/catalog.php?record_id=13362

[9] National Research Council. (2015). *Reaching students: What research says about effective instruction in undergraduate science and engineering.* Washington, DC: National Academies Press. Retrieved from www.nap.edu/download.php?record_id=18687

[10] Bailey, T. R., Jaggars, S. S., & Jenkins, D. (2015). *Redesigning America's community colleges: A clearer path to student success*. Cambridge, MA: Harvard University Press.

[11] Smith, D. (Ed.). (2015). *Vision and change in undergraduate biology education: Chronicling change, inspiring the future*. Washington, DC: AAAS. Retrieved from visionandchange.org/files/2015/07/VISchange2015_webFin.pdf

The IUSE framework relies upon the following five investment strategies:

- **Build core knowledge through research and development (R&D):** R&D investments will grow the evidence base on how best to improve undergraduate education through education research, including discipline-based education research.[12]
- **Implement and scale evidence-based practices and tools:** These investments will allow for the execution of a program or activity by 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 that can help in understanding the impacts of intervention and generating new questions that need examination.
- **Catalyze departmental and institutional transformation:** This funding supports design and implementation of models for systemic improvement.
- **Scholarship programs:** Direct support to students to encourage entry and retention in STEM fields.
- **Disciplinary research experiences for students:** This funding engages students in research.

FY 2018 Investments

A total of $96.5 million for IUSE is requested in FY 2018.

The Directorate for Education and Human Resources (EHR) will explore allocating a portion of the IUSE: EHR budget to establish an IUSE Collaborative Opportunities Fund (ICOF). The fund will be used to incentivize cross-directorate collaboration to identify thematic areas of emphasis that target pressing challenges in undergraduate STEM education either in specific disciplinary domains or in interdisciplinary areas of convergent research. Once such themes are identified, cross-directorate teams of program staff will issue calls for proposals under the IUSE: EHR umbrella program with all aspects of proposal processing and decision-making managed by the cross-directorate teams and with funding from participating directorates. The ICOF mechanism will be available to use in all three pooled IUSE goals as appropriate.

In FY 2018, $15.0 million is included for IUSE: Hispanic Serving Institutions (IUSE: HSI), with funding provided through the Division of Undergraduate Education and the Division of Human Resource Development. The primary goals of the IUSE: HSI activity are to promote research on engaged student learning at HSIs, to incentivize institutional and community transformation, and to promote fundamental research about what it takes to diversify and increase participation in STEM effectively, including research that improves our understanding of how to build institutional capacity at HSIs. These activities will address the Nation’s need to make the STEM workforce more inclusive.

Goal 1: Improve STEM learning and learning environments

- EHR will continue to develop indicators, metrics, and assessments to measure readiness for and progress toward widespread use of evidence-based resources in undergraduate STEM instruction. Program staff will seek to leverage any prior efforts for gathering data on indicators as a part of IUSE monitoring and evaluation and will use findings to shape future cross-directorate collaborations that enlarge the core IUSE investment activities.
- In EHR, applied research aimed at enabling improvements in undergraduate education at scale will continue to be a priority.
- Existing core IUSE investments, e.g. Research Coordination Networks: Undergraduate Biology Education (RCN: UBE), will present opportunities to make further progress on particular challenges facing the undergraduate enterprise in those domains.
- Themes associated with the NSF Big Ideas will present opportunities to leverage the ICOF approach, particularly with respect to interdisciplinary efforts.

[12] Op. cit., National Research Council. (2012).

Goal 2: Broaden participation and institutional capacity for STEM learning

- Several EHR programs with a broadening participation focus or opportunity—Louis Stokes Alliances for Minority Participation (LSAMP), Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), Tribal Colleges and Universities Program (TCUP), Advanced Technological Education (ATE), and Robert Noyce Teacher Scholarship Program (Noyce)—will explore alignment within the IUSE framework beginning in FY 2018.
- The IUSE: Pathways into Geoscience (IUSE: GEOPATHS) commitment to fostering broader and more inclusive pathways into careers in the geosciences will continue; as will the IUSE: Polar Research (IUSE: PLR) investment.
- Related efforts in the Directorate for Computer and Information Science and Engineering (CISE) to broaden participation will explore partnerships with relevant EHR programs, such as those mentioned above.

Goal 3: Build the STEM Workforce for Tomorrow

- Thematic evaluation begun in FY 2017 will continue with a goal of understanding how programs that directly support students with scholarships—e.g. Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM), Noyce, and CyberCorps®: Scholarship for Service (SfS)—contribute to workforce development and STEM degree completion for diverse populations.
- Leadership of the NSF directorates, with input from a Research Experiences for Undergraduates (REU) Coordinating Committee, will seek to build on prior discussions and expand the STEM research and experiential learning opportunities available to undergraduate students in NSF-funded large facilities, national laboratories, and centers.
- The IUSE: GEOPATHS program will seek to expand its efforts to 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. Here there is an opportunity to leverage current activities supported by the ATE program.
- Projects in the IUSE: EHR portfolio will be encouraged to establish collaborations with the growing cohort of NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science) Design and Development Launch Pilots and the NSF INCLUDES Alliances as they are awarded, to amplify each other's impact.
- CISE will explore issuing a DCL or solicitation focused on knowledge generation and implementation of new strategies for undergraduate education in computer science, particularly in the face of growing enrollments and interest in computing as well as the growing support for curricular approaches that acknowledge the intersection of computer science and other disciplines, collectively referred to as "CS+X," where "X" is a placeholder for other disciplines.
- NSF will collaborate again with the American Association of Community Colleges to sponsor and organize the Community College Innovation Challenge.

Improving Undergraduate STEM Education
Funding by Directorate
(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$2.74	-	$2.50
CISE	1.98	-	2.00
EHR	87.00	-	87.00
ENG	6.90	-	-
GEO	6.14	-	5.00
Total, IUSE	**$104.77**	**-**	**$96.50**

INCLUSION ACROSS THE NATION OF COMMUNITIES OF LEARNERS OF UNDERREPRESENTED DISCOVERERS IN ENGINEERING AND SCIENCE (NSF INCLUDES) $14,880,000 +$910,000 / 6.5%

Overview

National Science Foundation Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) is one of the agency's 10 Big Ideas. It aims to develop a talented, innovative, and capable science and engineering workforce that reflects the diversity of our society. If the United States is to remain the world leader with respect to innovations and discoveries in science, technology, engineering, and mathematics (STEM), it must identify and develop talent from all sectors of our society to become tomorrow's STEM professionals. Indeed, providing opportunities and support for members of all communities and sectors across the Nation is both necessary for the Nation's economic welfare and necessary as part of NSF's commitment to equity.

NSF INCLUDES began in FY 2015 and is expected to run until FY 2025.

The NSF INCLUDES program rests on principles of social innovation and the role of networks and organizational partnerships in enabling sustainable and scalable changes in systems and is based on the approach of collective impact.[13] Some key tenets in the design of NSF INCLUDES include the following:

- Strategies that rely on alliances and networks that include community-based organizations, local education policy makers, foundations, not-for-profit organizations, and industry (not all of which have STEM as their primary focus); measurable outcomes; a commitment to making change at scale;
- Ongoing implementation research and evaluation to inform mid-course adjustments;
- On-ramps designed to involve other networks, alliances, and science and engineering organizations; and
- A national network supported by a backbone organization.

Goals

The long-term strategy of NSF INCLUDES is to fund new research, models, and partnerships that lead to measurable progress at the national level and to scale effective approaches to diversity and inclusion in STEM. This will be achieved, in part, by increasing coherence and leveraging synergies across the NSF portfolio. The multi-year goals and abbreviated objectives are:

- Goal 1: Synthesize and build the research base for broadening participation in STEM and foster the spread and adaptation of proven effective practices.
- Goal 2: Support the identification and development of a set of shared goals and objectives developed by stakeholders, including those from specific STEM disciplines.
- Goal 3: Support local/regional, discipline-specific, and crosscutting multi-stakeholder partnerships and networks (INCLUDES Alliances) as well as an NSF INCLUDES National Network.[14]

FY 2018 Investments

Funding levels in FY 2018 are expected to increase 6.1 percent over the FY 2016 Actuals to fund the NSF INCLUDES Alliances and support the development and expansion of the INCLUDES National Network and the continuation of on-ramping activities.

- Design and Development Launch Pilots and Alliances will include innovative broadening participation

[13] Kania, J., & Kramer, M. (Winter 2011). *Collective impact*. Stanford Social Innovation Review. (See http://ssir.org/articles/entry/collective_impact)

[14] See Footnote #1. 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.

research components. Existing broadening participation programs will also highlight opportunities to support broadening participation research.
- Dear Colleague Letters and innovative tracks in broadening participation programs will be used to continue to build on-ramps between the current portfolio and NSF INCLUDES, in addition to supporting broadening participation research. NSF INCLUDES Alliances and Backbone Organizations will also be funded in FY 2018.
- Virtual and face-to-face meetings with principal investigators will build community across Design and Development Launch Pilots and Backbone Organizations funded in FY 2016 and FY 2017 and the newly funded Alliances, creating the foundation for the NSF INCLUDES National Network.
- External evaluation experts and NSF staff will develop and refine the theory of action/logic framework for each of the major investment goals of NSF INCLUDES, including common measures and indicators, which will be used to create annual metrics and ambitious short- and long-term targets.

NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
BIO	$1.40	-	$1.40
CISE	1.72	-	1.78
ENG	1.41	-	1.40
GEO	2.56	-	2.20
MPS	2.14	-	2.60
SBE	0.55	-	0.50
OIA	1.90	-	2.00
EHR	2.28	-	3.00
Total, NSF INCLUDES	**$13.97**	**-**	**$14.88**

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 (S&E). Today, emerging fields of S&E increasingly demand efforts across institutions, disciplines, and national boundaries and rest on the use of sophisticated data infrastructure, instruments, and networks of researchers. 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 to provide a supply of scientists and engineers who not only meet the needs of the STEM enterprise but who also 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.

Goal

The goal of NSF's 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 S&E 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 do the following:

- Support training in areas of national S&E 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 (GRF) 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[15] as ways to better prepare graduates for a broad range of careers. GRF 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. GRF 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,

[15] 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

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 Public Law Number: 113-274, establishing 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 members of the master teacher cohort at the graduate level and funds innovation and development in STEM teacher education approaches. In addition to GRF, NRT, SfS, and Noyce, 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 2018, NSF directorates will be 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. 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. The Division of Graduate Education (DGE) component of EHR's core research program will also emphasize research on the development of the STEM workforce.

Investment Framework

<u>Graduate Research Fellowship Program (GRF)</u>

The goal of GRF is to help build the U.S. STEM human capital necessary to ensure the Nation's leadership in advancing innovations in S&E. GRF 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).

GRF noteworthy activities are as follows:

- Program innovation has focused on professional development initiatives such as GROW and GRIP. The plans for evaluating GROW started in FY 2017, and the plans for evaluating GRIP will begin in FY 2018.
- The pilot survey and initial data collection for longitudinal monitoring of career outcomes of GRF recipients 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 GRF 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 GRF. In FY 2018, 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 GRF awards. The GRF 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. DGE will pilot activities in FY 2018 that promote professional development opportunities, preparing graduate students for careers in industry.

- In 2018, GRF will continue to partner with the Established Program to Stimulate Competitive Research (EPSCoR) to provide outreach to students and faculty in EPSCoR jurisdictions, with a special focus on minority-serving institutions located in EPSCoR jurisdictions.

Graduate Research Fellowship Program Funding by Account

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Education and Human Resources	$166.38	-	$123.27
Research and Related Activities	165.96	-	123.27
Total, GFR	**$332.34**	**-**	**$246.54**
Number of New Fellows	2,000	-	1,000
Projected Fellows on Tenure[1]	5,702	-	5,000

[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.

<u>NSF Research Traineeship (NRT)</u>

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. 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 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 2018, the funding for IGE is $4.0 million.

In FY 2018, NRT will support new STEM graduate education pilots and models in order to transform current practices in graduate education. Additionally, the NRT traineeship track will continue to solicit proposals in the NSF-wide priority research areas. Investigator-initiated interdisciplinary-themed proposals outside the priority research themes will continue to be accepted.

NSF Research Traineeship Funding by Directorate
(Dollars in Millions)

Directorate	FY 2016 Actual[1]	FY 2017 (TBD)	FY 2016 Request[2]
BIO	$2.33	-	-
CISE	7.69	-	3.00
EHR	31.03	-	33.05
ENG	2.59	-	-
GEO	5.26	-	3.05
MPS	4.47	-	1.00
SBE	2.60	-	-
Total, NRT	**$55.98**	**-**	**$40.10**

[1] Outyear commitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the FY 2016 Actual for NRT and were $5.91 million.
[2] EHR's NRT funding includes $4.0 million for Innovation in Graduate Education (IGE) as a track within the NRT program in FY 2018.

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.

FY 2018 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request
$49.98	-	$40.00

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 and the numbers of persons with disabilities who enter and complete STEM graduate education and postdoctoral training, so numbers reach the level representative of the available pool.

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, Alaska 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 per 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 2018, LSAMP-BD will continue to collaborate with GRF on effective approaches to increase the diversity of the GRF 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 H-1B Nonimmigrant Petitioner Account receipts.

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. See the H-1B Nonimmigrant Petitioner Fees section in the EHR chapter for more information.

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 track**,** funding is provided to support STEM professionals who enroll as NSF Teaching fellows in master's degree programs leading to teacher certification or licensing to teach a STEM discipline in an elementary or secondary school by providing academic courses, professional development, and salary supplements while they are fulfilling a four-year teaching commitment in a high-need school district. The Noyce NSF Master Teaching Fellowship track provides support to experienced and exemplary K-12 STEM teachers, who are certified/licensed teachers that either possess a master's degree or have a bachelor's degree and are enrolled in a master's degree program in their field. These fellows participate in mentoring and professional development activities to become highly effective master teachers and teacher leaders and are provided salary supplements 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)

Program	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
AGEP	$8.00	-	$7.00
LSAMP-BD	10.75	-	11.00
S-STEM	140.47	-	75.00
Noyce Teaching and Master Teaching Fellows (10A)	24.51	-	20.00
Total	**$183.72**	**-**	**$113.00**

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 2016[1]	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change Over FY 2016 Actual Amount	Percent
Centers for Analysis & Synthesis	1995	4	$18.60	-	$6.00	-$12.60	-67.7%
Centers for Chemical Innovation[2]	1998	9	28.10	-	21.60	-6.50	-23.1%
Engineering Research Centers	1985	20	56.39	-	57.50	1.11	2.0%
Materials Centers	1994	21	55.54	-	55.00	-0.54	-1.0%
Nanoscale Science & Engineering Centers[3]	2001	2	6.74	-	-	-6.74	-100.0%
Science & Technology Centers	1987	12	45.08	-	60.90	15.82	35.1%
Totals		**68**	**$210.44**	**-**	**$201.00**	**-$9.44**	**-4.5%**

[1] Counts include centers that received no-cost award extensions in FY 2016 but no additional funding.

[2] This presents Phase II CCI awards only. The smaller, developmental Phase I awards do not meet the criteria as formal NSF Centers and so are not captured here.

[3] The NSEC program will sunset as planned in FY 2017 as final award increments are made.

Description of Major Changes

Centers for Analysis and Synthesis – BIO

The FY 2018 Request of $6.0 million, $12.60 million below the FY 2016 Actual, will fund the National Socio-Environmental Synthesis Center (SESync). This center underwent external review in FY 2016 and was granted a five-year renewal award that started in FY 2016 and will continue through FY 2020. SESync uses synthetic approaches and provides computational support and training to enable interdisciplinary research teams, postdoctoral fellows, and graduate students, to advance the frontiers of scientific understanding of environmental complexity, and to address pressing societal challenges.

The ten-year center awards for CyVerse (formerly the Plant Science Cyberinfrastructure Collaborative, or iPlant) and the National Institute for Mathematical and Biological Synthesis (NIMBioS) are sunsetting as planned in FY 2017.

Centers for Chemical Innovation (CCI) – MPS

The CCI program explores major, long-term research challenges, producing transformative research that leads to innovation and attracts broad scientific and public interest. Centers often partner with industry, government laboratories, and international organizations to address energy production and storage, sustainable production of commercial chemicals such as polymers and nanomaterials, and complex single-molecule measurements at unprecedented time and spatial resolution.

The CCI program makes awards at two levels: smaller Phase I (three-year awards) for center development, and larger Phase II for full centers (five-year awards with the potential for renewal for up to a total of ten years). Phase I awards are considered part of CHE's core research program investments as they fall under the funding threshold for formal NSF center awards. In FY 2018, the CCI program (-$6.50 million to a total of $21.60 million) is expected to fund six Phase II Centers (two centers have sunset since FY 2016). These six Phase II CCIs will be supported at a reduced level relative to the standard center award of $4.0 million per year. NASA is expected to provide co-funding support through an ongoing interagency agreement.

In FY 2018, CCI Solar - An NSF Center for Innovation in Solar Fuels will sunset as expected. The Chemistry at the Space-Time Limit (CaSTL) Center will be in its 5th year and under consideration for renewal. The other five centers will continue in Phase II status. An external program evaluation for the CCI program is expected to begin in FY 2018 and be 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 a fifth-year renewal review. This midpoint review will determine if they are: structured effectively to meet program goals; 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 arose from discussions NAE held with the NRC on the future of NSF's center-based, multidisciplinary engineering research. The project includes a study to articulate a vision for the future of NSF–supported center-scale, multidisciplinary engineering research. A report is expected to be delivered at the end of April 2017.

At the FY 2018 Request level, 14 ERCs will be funded at $57.50 million (+$1.11 million to a total of $57.50 million). The program requires an increased investment to support planned growth of the Class of 2015 and Class of 2017 ERCs. 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. These centers address fundamental grand challenge research problems of intellectual and strategic importance of a complexity requiring collaboration among several disciplines. As evidenced in the number of patents and start-up companies generated, MRSECs advance U.S. competitiveness and innovation and are key in 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 and Research Experiences for Undergraduates (REU) program assessment and evaluation. The MRSECs, through a center-wide activity, support over 230 REU students each year.

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 2018 Request (-$540,000 to a total of $55.0 million) represents a very small reduction in the program and will support approximately 20 MRSECs. MRSEC competitions are held every three years. Twelve centers were awarded as the result of the last competition 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.

Science and Technology Centers: Integrative Partnerships (STC) - 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; new ways of handling the extraction, manipulation, and exchange of information; new nano-atomic scale imaging modalities, 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 2018 Request of $60.90 million (+$15.82 million to a total of $45.08 million) 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 2016

	Number of Participating Institutions	Number of Partners	Total FY 2016 NSF Support ($ in millions)	Total Leveraged Support ($ in millions)	Number of Participants
Centers for Analysis & Synthesis	2,416	981	$19	$0	16,532
Centers for Chemical Innovation	91	124	28	6	748
Engineering Research Centers	836	399	56	134	4,771
Materials Centers	367	263	56	44	4,500
Nanoscale Science & Engineering Centers	700	346	7	25	4,000
Science & Technology Centers	14	135	45	11	1,457

Number of Participating Institutions: All academic institutions participating in activities at the centers.

Number 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 2016

Center	Institution	State
Centers for Analysis and Synthesis		
National Evolutionary Synthesis Center[16]	Duke, NC State, U of North 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[17]		
Center for Aerosol Impacts on Climate and the Environment	U of California-San Diego	CA
Center for Chemical Evolution	Georgia Institute of Tech	GA
Center for Chemical Innovation in Solar Fuels	California Institute of Tech	CA
Center for Enabling New Technologies through Catalysis	U of Washington	WA
Center for Selective C-H Functionalization	Emory	GA
Center for Sustainable Materials Chemistry	Oregon State	OH
Center for Sustainable Nanotechnology	U of Wisconsin	WI
Center for Sustainable Polymers	U of Minnesota	MN
Chemistry at the Space-Time Limit	U of California-Irvine	CA
Engineering Research Centers		
Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)	North Carolina State	NC
Bio-mediated and Bio-inspired Geotechnics (CBBG)	Arizona State	AZ
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	MA
Compact and Efficient Fluid Power (CCEFP)[1]	U of Minnesota	MN
Future Renewable Electric Energy Delivery and Management Systems (FREEDM)	North Carolina State	NC
Integrated Access Networks (CIAN)	U of Arizona	AZ
Mid-Infrared Technologies for Health and the Environment (MIRTH)[1]	Princeton	NJ
Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)	U of Texas	TX
Nanotechnology Enabled-Water Treatment Systems (NEWT)	Rice University	TX
Optimization for Electro-thermal Systems (POETS)	U of Illinois	IL
Quantum Energy and Sustainable Solar Technologies (QESST)	Arizona State	AZ
Re-inventing the Nation's Urban Water Infrastructure (ReNuWit)	Stanford	CA
Revolutionizing Metallic Biomaterials (RMB)	North Carolina A&T U	NC
Sensorimotor Neural Engineering (CSNE)	U of Washington	WA
Smart Lighting	Rensselaer Polytechnic Institute	NY
Structured Organic Particulate Systems[1]	Rutgers	NJ
Synthetic Biology (SynBERC)[1]	U of California-Berkeley	CA
Translational Applications of Nanoscale Multiferroic Systems (TANMS)	U of California-Los Angeles	CA
Materials Centers		
Brandeis Bioinspired Soft Materials 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
Center for Nanostructured Interfaces	U of Wisconsin	WI
Center for Photonic and Multiscale Nanomaterials	U of Michigan	MI

[16] These centers received no-cost award extensions in FY 2016 but no additional funding.
[17] This presents Phase II CCI awards only. The smaller, developmental Phase I awards do not meet the criteria as formal NSF Centers and so are not captured here.

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 Superstratic And Superatomic Solids	Columbia	NY
Cornell Center for Materials Research	Cornell	NY
Harvard Materials Research 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	U of Minnesota	MN
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
Research Triangle Materials Research Science and Engineering Center	Duke, North Carolina State, NC Central U, U of North Carolina	NC
Soft Materials Research Center	U of Colorado	CO
Nanoscale Science and Engineering Centers		
Center for the Environmental Implications of Nanotechnology (CEINT)	Duke	NC
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	MI
Biology with X-Ray Free Electron Lasers	SUNY Buffalo	NY
Center for Brains, Minds, and Machines: The Science and the Technology of Intelligence	Massachusetts Institute of Tech	MA
Center for Bright Beams	Cornell	NY
Center for Cellular Construction	U of California-San Francisco	CA
Center for Dark Energy Biosphere Investigations	U of Southern California	CA
Center for Emergent Behaviors of Integrated Cellular Systems	Massachusetts Institute of Tech	MA
Center for Energy Efficient Electronics Science	U of California-Berkeley	CA
Center for Engineering MechanoBiology	U of Pennsylvania	PA
Center for Integrated Quantum Materials	Harvard	MA
Science and Technology Center on Real-Time Functional Imaging	University of Colorado	CO
Center for Science of Information	Purdue	IN

SELECTED CROSSCUTTING PROGRAMS

Many investments at NSF draw on interdisciplinary teams from across the Foundation and are supported by multiple directorates. Other parts of this chapter, NSF-Wide Investments, 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). Additional 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.

ADVANCE

In FY 2018, $4.90 million in funding is requested for the ADVANCE program, a decrease of $9.96 million below the FY 2016 Actual. In FY 2018, ADVANCE will not make any new program commitments. Funding for ADVANCE in FY 2018 is provided by the Directorates for Biological Sciences (BIO); Education and Human Resources (EHR); Geosciences (GEO); Mathematical and Physical Sciences (MPS); and Social, Behavioral and Economic Sciences (SBE).

Faculty Early Career Development (CAREER)

The FY 2018 Request provides $242.20 million for the CAREER program, a decrease of $38.45 million from the FY 2016 Actual. This funding will support approximately 440 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, the Directorates for Computer and Information Science Engineering (CISE), Engineering (ENG), GEO, MPS, and SBE.

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*. In FY 2016, NSF determined that dedicated funding is not necessary to encourage the kinds of projects supported through INSPIRE. In FY 2017, a new funding mechanism encompassing elements of INSPIRE was developed, Research Advanced by Interdisciplinary Research and Engineering (RAISE). In FY 2018, Office of Integrative Activities co-funding is eliminated and each directorate will support bold, potentially transformative interdisciplinary research through the RAISE mechanism, coordinating with other directorates as appropriate.

Long-Term Ecological Research (LTER)

The FY 2018 Request provides $29.42 million for LTER; this is $1.20 million below the FY 2016 Actual. 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 28 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 challenges. LTER projects represent a diversity of habitats in continental North America, the Caribbean, Pacific Ocean, Arctic, and the Antarctic; including coral reefs, arid grasslands, estuaries, lakes, prairies, forests, alpine and Arctic tundra, urban areas, and agroecosystems. The support for LTER in FY 2018 will be used to sustain site-specific research activities examining ecological and 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.

The National Ecological Observatory Network (NEON) infrastructure will be co-located at eight 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 2018, $74.71 million in funding is requested for the REU Sites and Supplements program, a decrease of $23.01 million below the FY 2016 Actual. NSF's ongoing support for REU reflects the importance of undergraduate research experiences in building students' interest and competence in STEM disciplines. 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 Disabilities Education (RDE)
The FY 2018 Request for NSF's RDE program totals $5.50 million; this is $3.79 million below the FY 2016 Actual. The RDE activity advances the goal of broadening the participation and achievement of postsecondary students with disabilities in STEM. RDE proposals are accepted in all fields of science and engineering supported by NSF, particularly research on learning and education. Planned funding for RDE is provided through EHR/DRL, with additional funding provided by EHR/HRD, CISE, and SBE for meritorious projects relevant their communities.

Research in Undergraduate Institutions (RUI)
The FY 2018 Request for NSF's RUI program totals $35.34 million; this is $8.20 million below the FY 2016 Actual. The RUI activity seeks to support 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Biological Sciences	$48.80	-	$42.50
Computer and Information Science and Engineering	13.55	-	12.10
Education and Human Resources	2.50	-	2.50
Engineering	207.50	-	168.50
Geosciences	0.30	-	-
Mathematical and Physical Sciences	237.10	-	162.53
Social, Behavioral, and Economic Sciences	0.53	-	0.40
Office of International Science and Engineering	0.10	-	0.10
Total, NNI	**$510.38**	**-**	**$388.63**

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 nanometer 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 2016 NNI Strategic Plan and the NNI Supplement to the President's Budget for Fiscal Year 2017.[18] Funding by PCA is shown at the end of this discussion.

FY 2018 NNI Funding

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 2018.

Overall, total NNI funding in the FY 2018 Request is $388.63 million. Several new directions planned for FY 2018 are nanotechnology for brain-like computing, including highly energy efficient systems and intelligent cognitive assistants; nanobiomanufacturing, including cell technology; food-energy-water processes, including nanofiltration at end-users; nanomodular materials and systems by design, including three-dimensional nanoscale materials; and emerging aspects of nanoelectronics, photonics, papertronics, and neuroscience. NSF sponsors an annual NSE grantee conference to assess the progress in nanotechnology and facilitate identification of new research directions.[19]

[18] www.nano.gov
[19] 2016 Nanoscale Science and Engineering Grantees Conference: www.nsf.gov/nano and www.nseresearch.org/2016/

In FY 2018, NSF support will increasingly focus on convergence research and education activities in confluence with other priority areas such as: Networking and Information Technology Research and Development (NITRD) and the National Strategic Computing Initiative (NCSI); Science, Engineering, and Education for Sustainable Chemistry, Engineering and Materials (SusChEM); 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 Nanoscale Engineering Research Centers (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. Nanotechnology research will contribute and synergize in the future with eight of NSF's Big Ideas.

Various assessments and reports have assisted with informing plans for NNI going into the future. NSF sponsored an international study on long-term research entitled *Nanotechnology Research Directions for Societal Needs in 2020.*[20] It provides an assessment of nanotechnology development in the ten year period (2000-2010) and a vision of the field for the following 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*[21] evaluating the convergence of nanotechnology with other emerging areas. A follow-up report on *Science and Technology Convergence* was completed in 2016. A study on *Nanomodular Materials and Systems by Design* to identify international activities and research directions was completed in 2016.[22] The 2016 reports *Energy-Efficient Computing from Devices to Architectures* and *Intelligent Cognitive Assistants* were completed in collaboration with the Semiconductor Industry Association (SIA) and the Semiconductor Research Corporation (SRC). The purpose of these reports was to define Grand Challenges, one of them being Brain-like Computing. The reports address 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. [23,24]

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.[25] 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 be funded at a total of $106.87 million. The Water Sustainability through

[20] NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/
[21] NSF/WTEC 2013, Springer, available on www.nsf/gov/nano and www.wtec.org/NBIC2-Report/
[22] www.wtec.org/nmsd/
[23] http://1.usa.gov/1Fg90Dw; https://www.src.org/nri/energy-efficient-computing-workshop.pdf
[24] www.semiconductors.org/issues/research/research/
[25] www.nano.gov/nni-pca

Nanotechnology NSI began in FY 2016 and will continue in FY 2018. Special emphasis will be on:

- Sustainable Nanomanufacturing ($29.77 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, cellulosic nanomaterials, nanobiomanufacturing and nanomodular systems. This initiative will establish manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems. A program solicitation, *Scalable Nanomanufacturing for Integrated Systems*, and a DCL, *Advanced Manufacturing Research to Address Basic Research Enabling Innovation at Manufacturing USA Institutes*, are planned for 2017 and 2018. Engineering biology at the nanoscale for advanced manufacturing activities in the Directorates for Biological Sciences (BIO), Engineering (ENG), and Mathematics and Physical Sciences (MPS) are being organized for 2017 and 2018. Methods for nanomanufacturing design are in synergy with the Materials Genome Initiative.
- Nanoelectronics for 2020 and Beyond ($37.35 million)—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 beyond Moore's Law. Collaboration in the Nanoelectronics Research Initiative with SRC (n-CORE, STARnet, nanobio) and the National Institute of Standards and Technology (NIST) is planned to continue in 2017 and 2018 with a focus on *Energy Efficiency Devices*, *Systems and Architectures (E2CDA*). Research is planned on the NNI Grand Challenge *Brain-like Computing* and *Intelligent Cognitive Assistants*. Two examples of active centers are the Science and Technology Center (STC) on Quantum Materials and Devices at Harvard University and the Materials Research Science and Engineering Center (MRSEC) on Quantum and Spin Phenomena in Nanomagnetic Structures at the University of Nebraska, Lincoln. NSF will increase coordinated research on Quantum leap, one of the NSF's Big Ideas.
- Nanotechnology Knowledge Infrastructure ($19.68 million)—Activities surrounding the fundamental, interconnected elements of collaborative modeling and computer simulation, an interacting cyber-toolbox, and data infrastructure for nanotechnology. 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 has been re-competed for 2017-2022. Program solicitations, "Cyber-Enabled Discovery and Innovation" and "Software Infrastructure for Sustained Innovation", will contribute to data infrastructure, software advances, and high throughput computation.
- Nanotechnology for Sensors and Sensors for Nanotechnology ($8.64 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 and biophotonics in the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) in ENG will support this effort.
- Water Sustainability through Nanotechnology ($11.43 million)—Takes advantage of the unique properties of engineered nanomaterials and systems to increase water availability; improve the efficiency of water delivery; and enable next-generation water monitoring systems. The Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) initiative supports projects in nanotechnology. Besides core nanoscience-related programs on water filtration and applications, the NERC for Nanotechnology Enabled Water Treatment Systems (NEWT) led by Rice University, funded between 2015 and 2020, aims at developing high-performance water treatment systems that will: broaden access to clean drinking water from a variety of unconventional sources (briny well water,

seawater, wastewater), and enable industrial wastewater reuse at remote locations such as oil and gas fields.

PCA 2: Foundational Research

The FY 2018 Request includes $190.17 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 2018 Request includes $37.90 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. Core programs in ENG, Computer and Information Science and Engineering (CISE) and MPS support development of new principles, design methods and constructive solution for nanodevices. A special focus is on smart autonomous nanoscale-based devices and systems.

PCA 4: Research Infrastructure and Instrumentation

The FY 2018 Request includes $42.59 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. NSF funded an award of about $16 million per year for the National Nanotechnology Coordinated Infrastructure (NNCI) sites for 2015-2020, whose national coordination office was added in FY 2016. Other STC, ERC, and MRSECs have a focus supporting NNI such as the Center for Cellular Construction at the University of California-San Francisco (annual award since 2016 is approximately $5 million) and two NERC on nanobio and cell technology. NSF continues to sponsor nanotechnology education and related activities, such as disseminating the video series with NBC Learn, *Nanotechnology: Super Small Science*. Other examples are high-school student competitions "Video nanotechnology student competition" and "Generation Nano" sponsored by ENG, MPS and the NSF Office of Legislative and Public Affairs.[26]

PCA 5: Environment, Health, and Safety

In FY 2018, NSF will continue its funding for the Environment, Health, and Safety (EHS) PCA at $11.10 million, representing roughly 2.8 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. The Nano EHS Program within the Engineering Directorate has changed to *Biological and Environmental Interactions of Nanoscale Materials.*

[26] www.nsf.gov/news/special_reports/gennano/index.jsp

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 the National Institute of Standards and Technology (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);
- Collaboration with the NIST, Air Force Office of Scientific Research (AFOSR) Defense Advanced Research Projects Agency (DARPA), and SRC (n-CORE, STARnet) to continue in 2017 and 2018 with a focus on "Energy Efficiency Devices, Systems and Architectures (E2CDA)" and "Brain-like Computing";
- Nanoelectronics—NIST, Department of Defense (DOD), DOE, Intelligence Community (IC)/Director of National Intelligence (DNI), and NASA;
- NNCI and NCN centers and networks—NSF with DOD, NASA, DOE, and NIH;
- Nanosensors—collaboration with NIOSH, NIH, FDA, NIST, DOD, NASA, NSF, and EPA;
- Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) program—NSF and USDA/NIFA joint solicitation;
- NSF collaboration with NIOSH, National Cancer Institute (NCI), NIH, NIST, Pacific Northwest National Laboratory, and DOD, and many public- and private-sector partners with the Nanoinformatics Consortium: UCLA, the National Nanomanufacturing Network, nanoHUB, RTI International, MIT, and the NanoBusiness Commercialization Association.
- 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 2016 Actual	FY 2017 (TBD)	FY 2018 Request
1. Nanotechnology Signature Initiatives	$163.59	-	$106.87
Sustainable Nanomanufacturing	*37.22*	-	*29.77*
Nanoelectronics for 2020 and Beyond	*70.31*	-	*37.35*
Nanotechnology Knowledge Infrastructure	*23.86*	-	*19.68*
Nanotechnology for Sensors	*16.29*	-	*8.64*
Water Sustainability through Nanotechnology	*15.91*	-	*11.43*
2. Foundational Research	216.85	-	190.17
3. Nanotechnology-Enabled Applications, Devices, and Systems	55.87	-	37.90
4. Research Infrastructure and Instrumentation	56.51	-	42.59
5. Environment, Health, and Safety	17.56	-	11.10
Total, NNI	**$510.38**	**-**	**$388.63**

NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Biological Sciences	$99.00	-	$69.00
Computer and Information Science and Engineering	933.76	-	838.92
Education and Human Resources	9.50	-	9.50
Engineering	29.50	-	23.25
Geosciences	24.00	-	22.00
Mathematical and Physical Sciences	94.75	-	76.50
Social, Behavioral, and Economic Sciences	28.14	-	22.71
Total, NITRD	**$1,218.65**	**-**	**$1,061.88**

NSF is a primary supporter of the Networking and Information Technology Research and Development (NITRD) program, and NSF's NITRD portfolio includes all research, infrastructure, and education investments in the Directorate for Computer and Information Science and Engineering (CISE), as well as contributions from all other directorates across the agency, enabling investments in every NITRD Program Component Area (PCA). The Assistant Director for CISE is co-chair of the NITRD Subcommittee of the National Science and Technology Council's Committee on Technology. In addition, numerous NSF staff work in close collaboration with other NITRD agencies and participate at the co-chair level in most of the NITRD Interagency Working Groups.

NSF's FY 2018 Budget Request continues strong support for NITRD at a level of $1.06 billion. NITRD activities represent approximately 16 percent of NSF's FY 2018 Budget Request to Congress. CISE's support comprises 79 percent of NSF's NITRD activities.

The NITRD Subcommittee established a Fast-Track Action Committee (FTAC) in January 2016 to review the NITRD PCAs and their associated charges and definitions and to pursue and adopt changes as needed, beginning in FY 2018. The PCAs are the major subject areas under which the projects and activities coordinated through the NITRD program are grouped. These changes reflect the rapidly evolving IT R&D environment and the national priorities and focus areas on which the NITRD program's future direction is set.

Of the 10 PCAs in FY 2018, three are new: Computing-Enabled Human Interaction, Communication, and Augmentation (CHuman); Computing-Enabled Networked Physical Systems (CNPS); and Education and Workforce (EdW). Three of the PCAs were revised for FY 2018: High-Capability Computing Infrastructure and Applications (HCIA); Robotics and Intelligent Systems (RIS); and Software Design and Productivity (SDP). The remaining four are unchanged: Cyber Security and Information Assurance (CSIA); Enabling-R&D for High-Capability Computing Systems (EHCS); Large-Scale Data Management and Analysis (LSDMA); and Large-Scale Networking (LSN). Three of the 10 PCAs previously used to describe the NITRD portfolio were retired as part of this revision: Human-Computer Interaction and Information Management (HCI&IM); High-Confidence Software and Systems (HCSS); and Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW).

FY 2018 NSF Investments by Program Component Area (PCA)
The following information focuses on FY 2018 NSF investments, both new and continuing, by PCA.

CHuman ($79.63 million): CHuman will include CISE investment in Cyberlearning and Future Learning Technologies (CFLT), which will aim to integrate advances in technology with advances in understanding how people learn. CLFT will emphasize the use of technologies to support adult retraining and continuing education. It will also include CISE investment in Smart and Connected Health (SCH), which will focus on improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies. Understanding the Brain (UtB) investment in CHuman will enable the research needed to integrate computational models across scales and develop innovative neurotechnologies to monitor brain function.

The Directorate for Social, Behavioral, and Economic Sciences (SBE) will invest in CHuman by focusing on the impacts of the nature and dynamics of information technology on technical and social systems. CHuman will also include SBE investment in cyberinfrastructure related to its three surveys (American National Election Studies, the Panel Study of Income Dynamics, and the General Social Survey), which will enable examination of societal concerns, such as competitiveness, security, economic development, and well-being.

CNPS ($75.33 million): CNPS will include investments in advanced manufacturing, including cyber-manufacturing from CISE and the Directorate for Engineering (ENG). CISE investment in CNPS will also include Cyber-Physical Systems (CPS), enabling foundational interdisciplinary research and education in adaptive and pervasive smart systems supporting applications such as smart grid, intelligent transportation systems, and medical devices. Additionally, as part of CNPS, CISE investment in the NSF-wide Smart & Connected Communities (S&CC) will support interdisciplinary, integrative research and research capacity-building activities that improve understanding and design of intelligent infrastructure for communities, leading to enhanced quality of life for residents. Directorate for Biological Sciences (BIO) investment included in CNPS will expand and enhance access to the national resource of digital biological and paleontological data.

CSIA ($98.48 million): CSIA will include investment in the NSF-wide Secure and Trustworthy Cyberspace (SaTC) program and other related cybersecurity research. CISE investment in SaTC—in partnership with the Directorate for Education and Human Resources (EHR), ENG, Directorate for Mathematical and Physical Sciences (MPS), and SBE—will support foundational research necessary to ensure society's ubiquitous computing and communication systems are resistant to cyber-attacks and associated vulnerabilities, while enabling and preserving privacy and trust.

EdW ($68.89 million): EdW will include CISE and EHR investments in (1) Computer Science for All (CSforAll), which seeks to enable rigorous and engaging computer science education in schools across the Nation; (2) Improving Undergraduate STEM Education (IUSE), with a focus on novel approaches for "CS+X," enabling the diffusion of the fundamentals of computational thinking and computer science across a broad array of other disciplines at the undergraduate level; and (3) NSF Research Traineeships (NRT), which will support the development of bold, new, potentially transformative and scalable models for STEM graduate training focusing on research areas of national priority. It will also include CISE and EHR investments supporting workforce development in cybersecurity, enabling a growing pipeline of researchers, educators, and practitioners, as well as the development of a citizenry that understands the security and privacy of the digital systems on which society depends. Finally, EdW will include investment in NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES), the NSF-wide effort to increase the preparation, participation,

advancement, and potential contributions of those who have been traditionally underserved or underrepresented in STEM fields.
BIO investment focusing on advancing the Nation's ability to incorporate and apply biological knowledge to economic development and other issues of societal importance will also be included in EdW.

EHCS ($116.11 million): EHCS will include investment in the National Strategic Computing Initiative (NSCI), which will support advances in High-Performance Computing (HPC) systems, increasing the capacity, capability, and sustainability of an enduring national HPC ecosystem. CISE investment in NSCI will emphasize future HPC systems beyond the limits of current semiconductor technology, as well as emerging infrastructure, including quantum technologies, for all areas of science and engineering. MPS investment will 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 invest in fundamental research on innovative materials integration and novel phenomena associated with quantum information science, optical computing, and neuro-computing.

HCIA ($178.71 million): HCIA will include CISE investment on the development of software and algorithms for high-end computing systems as well as advanced computational infrastructure in alignment with NSCI. HCIA will also include CISE and MPS investments in new computational methods, algorithms, scientific databases, and other computational tools to support researchers in the mathematical and physical sciences as well as engineering through support for programs such as Computational and Data-Enabled Science and Engineering (CDS&E). The CISE investment in computational infrastructure as part of NSCI will be included in HCIA alongside GEO's support for EarthCube, a cyberinfrastructure investment for the geosciences. GEO's continued investment in the operations and maintenance of the National Center for Atmospheric Research's (NCAR) Wyoming Supercomputer facility and associated modeling efforts will also be included in HCIA. HCIA will include BIO investment on the application of HPC to a range of grand challenge problems in the biological sciences including, UtB, genotype to phenotype, and the environmental sciences.

LSDMA ($198.82 million): LSDMA will include CISE investments in the Harnessing the Data Revolution (HDR) Big Idea, including big data analytics and visualization tools through the Critical Techniques, Technologies and Methodologies for Advancing Foundations and Applications of Big Data Sciences and Engineering (BIGDATA); the development of a comprehensive, scalable data infrastructure as part of Data Infrastructure Building Blocks (DIBBs); and, jointly with MPS, Transdisciplinary Research in Principles of Data Science (TRIPODS), which brings together the statistics, mathematics, and theoretical computer science communities to develop the theoretical foundations of data science through integrated research and training activities.

Additional MPS investment will include research efforts to develop and advance theories and techniques for analyzing and extracting information from large and disparate data sets. ENG investment in 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, will be included. LSDMA will also include SBE investment in Resource Implementations for Data Intensive Research in the Social, Behavioral, and Economic Sciences (RIDIR) and BIO investment on integrative modeling of complex biological processes.

LSN ($128.24 million): LSN will include CISE investment in next-generation software-defined infrastructure through Tomorrow's Internet Project Office (TIPOFF). LSN will also include CISE investment in a set of Platforms for Advanced Wireless Research (PAWR) that enable research on topics ranging from dynamic spectrum sharing to mobility and to measurement and monitoring, thus advancing the next generation of high-performance, robust wireless networks. A portion of CISE investment in S&CC will be included in LSN.

RIS ($41.32 million): RIS will include CISE and ENG investments in the National Robotics Initiative (NRI) and research related to the design, application, and use of robotics to augment human function, promote human-robot interaction, and 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-time, real-world data, demonstrating a level of intelligence and adaptability seen in humans and animals. As development of this next generation of robotics proceeds, complete confidence in the robotic systems that work beside, or cooperatively with, people in application domains such as advanced manufacturing, emergency response, and health care becomes increasingly important.

SDP ($76.35 million): SDP will include CISE investment in Software Institutes for Sustained Innovation (SI2), a component of NSCI that catalyzes new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable. SDP will also include BIO investment in the interagency and international Collaborative Research in Computational Neuroscience (CRCNS), which is joint with CISE and other NSF directorates and offices. Through CRCNS, BIO will fund research involving the development of software and other computational tools to advance biological knowledge and computational innovations. As part of SDP, SBE will continue to collaborate with CISE on exploring the emerging interface between computer and information science and engineering and the social, behavioral, and economic sciences.

NITRD Funding by Program Component Area

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Computing-Enabled Human Interaction, Communications, Augmentation	$90.21	-	$79.63
Computing-Enabled Networked Physical Systems	85.93	-	75.33
Cyber Security and Information Assurance	111.67	-	98.48
Education and Workforce	76.44	-	68.89
Enabling-R&D for High-Capability Computing Systems	133.00	-	116.11
High Capability Computing Infrastructure and Applications	197.93	-	178.71
Large-Scale Data Management and Analysis	248.87	-	198.82
Large Scale Networking	138.94	-	128.24
Robotics and Intelligent Systems	48.92	-	41.32
Software Design and Productivity	86.73	-	76.35
Total, NITRD	**$1,218.65**	**-**	**$1,061.88**

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Total Funding for USGCRP

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Biological Sciences	$103.63	-	$94.00
Geosciences	185.94	-	140.00
Mathematical and Physical Sciences	8.00	-	-
Social, Behavioral and Economic Sciences	17.98	-	14.98
Office of Polar Programs	15.15	-	15.15
Total, USGCRP	**$330.70**	**-**	**$264.13**

NSF addresses global-change issues through investments that advance frontiers of knowledge, provide state-of-the-art instrumentation and facilities, develop new analytical methods, and enable cross-disciplinary collaborations while also cultivating a diverse, highly trained workforce and developing educational resources. NSF's global change-related programs support the research and related activities to advance fundamental understanding of physical, chemical, biological, and human systems and the interactions among them. NSF's existing programs encourage interdisciplinary approaches to studying Earth system processes and the consequences of change, including how humans respond to changing environments and the impacts on ecosystems and the essential services they provide. The Foundation's programs promote the development and enhancement of models to improve understanding of integrated Earth system processes and to advance predictive capability. NSF supports fundamental research on the processes used by organizations and decision makers to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of a changing and variable environment, as well as the antecedents of and consequences for human behavior. Long-term, continuous, and consistent observational records are essential for testing hypotheses quantitatively and are thus a cornerstone of global change research. NSF supports a variety of research observing networks that complement, and are dependent on, the climate monitoring systems maintained by its federal partners.

FY 2018 Areas of Emphasis

NSF funding for the U.S. Global Change Research Program (USGCRP) in the FY 2018 Request is $264.13 million. NSF's investments will continue to support research that contributes to the USGCRP Goal Areas to 1) Advance Science and 2) Inform Decisions. In FY 2018, NSF will continue to engage with other USGCRP agencies on priorities from 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. In addition, NSF will further seek the greater integration of social-science research, methodologies, and insights into understanding and supporting responses to global change, improving computing capacity, and maintaining needed observational capabilities over time. The major USGCRP foci for NSF include:

Goal 1: Advance scientific knowledge of the integrated natural and human components of the Earth system

Earth System Understanding: Improving our knowledge of Earth's past and present climate variability and change through Multidisciplinary Earth and Human System Understanding—NSF participates in the Earth System Understanding objective 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 global 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.

NSF also supports Earth System Understanding 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.

Integrated Observations and Integrated Modeling: Improving our capability to model and predict future conditions and impacts—NSF contributes to the Integrated Observations and Modeling objectives through its advanced capabilities to observe the physical, chemical, biological, and human components of the Earth system over multiple space and time scales. Facilities such as the Academic Research Fleet and the National Ecological Observatory Network (NEON) assist the Nation in gaining a fundamental scientific understanding of the Earth as well as monitor important variations and trends that allow the research community to examine major feedback processes between the climate and natural and human systems. Since there is increasingly deep interplay among observations and modeling at multiple spatial and temporal scales, a high priority will be given to developing more complete representations - models 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.

Goal 2. Inform Decisions: Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation

Inform Adaptation and Mitigation: Assessing the Nation's vulnerability to current and anticipated impacts of global change through the Science of Adaptation and Science to Information Adaptation Decisions—A key focus of the USGCRP is developing better means of assessing and responding to the impacts of global change as well as the vulnerability and resilience of both human and natural systems to those changes, particularly in highly sensitive regions such as the Arctic. NSF supports the Inform Adaptation and Mitigation objectives through research contributing to science of adaptation and science to inform adaptation decisions. 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, resiliency, biodiversity, ocean acidification, and vulnerable areas, particularly in the rapidly changing Arctic.

USGCRP Funding
(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
Integrated Observations	$80.56	-	$110.00
Multidisciplinary Earth and Human System Understanding	197.61	-	114.60
Integrated Modeling	36.78	-	26.78
Science of Adaptation and Science to Inform Adaptation Decisions	15.75	-	12.75
Total, USGCRP	**$330.70**	**-**	**$264.13**

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NSF PERFORMANCE FRAMEWORK

Introduction

Per the GPRA Modernization Act of 2010, this chapter, together with the Overview, contains basic information about NSF's mission and Strategic Plan, as well as NSF's FY 2018 Annual Performance Plan (APP), Major Management Challenges, and FY 2016 Strategic Objective Progress Update. Information about NSF's performance can also be found on the NSF site in the FY 2016 Annual Performance Report (APR), and the Performance and Financial Highlights Report.[1]

The FY 2018 Budget Request highlights NSF's priorities for crosscutting investments and organizational efficiencies. NSF's FY 2018 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 2018 APP also includes newer goals that focus on improving the quality of the reviews written by outside reviewers and fostering an inclusive culture within the agency.

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. NSF is in the process of developing a new Strategic Plan to begin in FY 2018.

[1] www.nsf.gov/about/performance

FY 2016 STRATEGIC OBJECTIVE PROGRESS UPDATES

In FY 2016, the National Science Foundation conducted Strategic Reviews (SRs) of the seven Strategic Objectives in its 2014-2018 Strategic Plan, in response to the requirement of the GPRA Modernization Act 2010 Section 1116(f). This table summarizes the analyses performed and the outcomes to date of each SR. The table also provides NSF's determination as to whether performance towards an Objective is making noteworthy progress, should pursue focused improvement, or neither.

Strategic Objective and Ranking	Summary of Strategic Review Analysis	Strategic Review Outcomes
Strategic Goal 1 Objective 1 Invest in fundamental research to ensure significant continuing advances across NSF science, engineering, and education. ***Not Ranked***	**Focus area: The Science of Broadening participation.** The Strategic Review investigated NSF's investment in the science of broadening participation (SBP), defined as fundamental social science and education research to identify and understand the factors that foster or hinder participation, retention, and success of members of underrepresented groups in STEM fields. SBP can help NSF enhance its investment in programs and activities that focus on building the capacity of the scientific workforce.	The SR identified the following action as follow-up: "Investigate efficient and effective means for synthesizing the results of SBP research, disseminating that knowledge, and utilizing it to improve the effectiveness of research and education programs." Discussions on how to implement this recommendation began in FY 2016.
Strategic Goal 1 Objective 2 Integrate education and research to produce a diverse STEM workforce with cutting-edge capabilities. ***Ranked as Noteworthy Progress***	**Focus area: Graduate Education.** The Strategic Review examined how NSF can improve measurement of its investments in graduate education in light of current trends in the diversity of career pathways of STEM graduate students.	The SR identified two follow-up actions: • Change the term for graduate students supported on grants from "research assistant" to "research trainee" as a mechanism to reinforce strategic and educational objectives. • Encourage NCSES to consider whether to revise the NSF/NIH Survey of Graduate Students and Postdoctorates in Science and Engineering to collect data on masters versus doctoral students separately. A suggestion to consider the impacts of the first recommendation was added to the Strategic Framework for Investments in Graduate Education, FY 2016-FY 2020. The second recommendation was completed in FY 2016.

Strategic Goal 1 Objective 3 Provide world-class research infrastructure to enable major scientific advances. ***Ranked as a Focus Area for Improvement*** **Strategic Goal 3 Objective 1** Build an increasingly diverse, engaged, and high-performing workforce by fostering excellence in recruitment, training, leadership, and management in human capital. ***Not Ranked*** **Strategic Goal 3 Objective 2** Use effective methods and innovative solutions to achieve excellence in accomplishing the agency's mission. ***Not Ranked***	**Focus area: Human Resources and Business Practices in the Oversight of Facilities.** The combined Strategic Review of three of NSF's Objectives focused on human resource and business practices pertaining to the NSF staff responsible for oversight of major facilities.	The SR identified a number of follow-up actions. Work to implement all of them began in FY 2016: • The Large Facilities Working Group will identify a minimum set of competencies needed by NSF staff responsible for the oversight of major facilities. • Directorates will ensure Position Descriptions and Individual Development Plans (IDPs) are up to date when staff are assigned to a given facility. • The Large Facilities Program Officer (PO) Forum will incorporate opportunities for facilities programs to present lessons learned or best practices that work within NSF culture. • The Large Facilities Office will explore options for improving informal knowledge transfer across organizational units. • NSF should seek opportunities to partner with other agencies (e.g. take NASA, DOE courses) and consider developing NSF-specific training where cost-effective. • LearnNSF should be modified to better capture informal learning activities.
Strategic Goal 2 Objective 1 Strengthen the links between foundational research and societal needs through investments and partnerships. ***Not Ranked*** **Objective 2** Build the capacity of the Nation to address societal challenges using a suite of formal, informal, and broadly available STEM educational mechanisms. ***Not Ranked***	**Focus area: The Broader Impacts (BI) criterion of NSF's merit review process.** The combined Strategic Review investigated the broader impacts (BI) criterion of NSF's merit review process (the other criterion is intellectual merit). Defined as, "the potential for the proposed activity to benefit society or advance desired societal outcomes," the BI criterion is the mechanism through which the merit review process communicates the importance of societal benefit to its potential awardees.	The SR recommended that NSF "Provide standard training on BI to program directors, panel reviewers, and COVs." This recommendation is being implemented. A video orientation to the review process, including a segment explaining the BI criterion, was developed in FY 2016 and is available to all program officers and panelists. The BI segment is also available to COVs.

FY 2018 ANNUAL PERFORMANCE PLAN

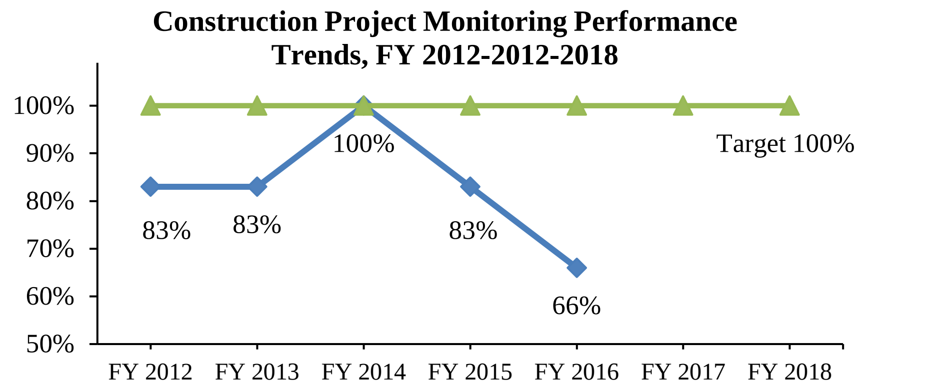
NSF's FY 2018 Annual Performance Plan reflects NSF's priorities as identified through its planning and budget process. The table below provides a summary of NSF's performance goals for FY 2018. The remaining pages of this section provide a detailed description of each goal along with the proposed target measures, milestones, or deliverables.

	Performance Goal	**Lead Organization**	**Goal Statement**
1	Ensure that Key Program Investments are on Track	BFA	Ensure that key FY 2018 NSF-wide program investments are implemented and on track.
2	Ensure that Infrastructure Investments are on Track	BFA	Ensure program integrity and responsible stewardship of major research facilities and infrastructure.
3	Use Evidence to Guide Management Decisions	OIRM	Use evidence-based reviews to guide management investments.
4	Make Timely Award Decisions	OIA/OD and BFA	Inform applicants whether their proposals have been declined or recommended for funding in a timely manner.
5	Improve Review Quality	OIA/OD	Improve the quality of written reviews of NSF proposals.
6	Foster a Culture of Inclusion	ODI/OD	Foster a culture of inclusion through change management efforts resulting in change leadership and accountability.

Goal 1: Ensure that Key Program Investments are on Track

Goal Statement	Ensure that key FY 2018 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	Each year, NSF highlights a number of cross-agency investments in the NSF-Wide Investments chapter of its Budget Request to Congress. Although the overall impact of these investments will not be realized for many years, tracking near-term indicators of implementation and progress can help the agency make formative changes or course corrections. 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 has been a goal since FY 2014. The list of monitored programs is subject to change each year based on investment priorities for a particular year.
Lead Organization/s	Office of Budget, Finance, and Award Management

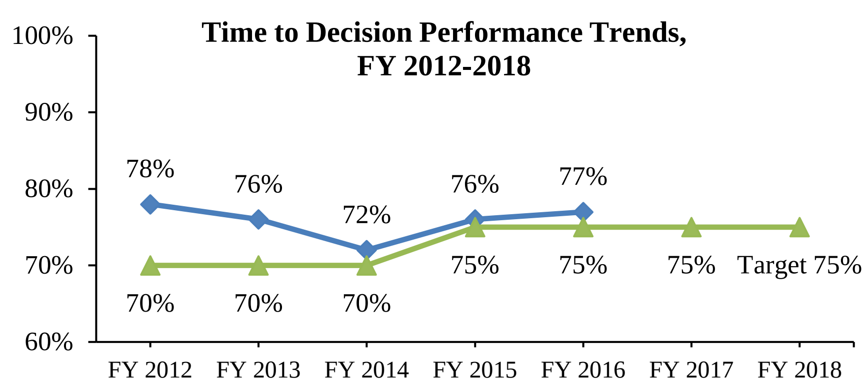
Goal 2: Ensure that Infrastructure Investments are on Track

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 10 percent complete, keep negative cost and schedule variance at or below 10 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 10 percent complete are not considered eligible for this goal because Earned Value Management (EVM) data are statistically less meaningful in early stages. The final Q4 EVM results are used to determine whether NSF has met this goal.
Trend Information	
Lead Organization/s	Large Facilities Office, Office of Budget, Finance, and Award Management

Goal 3: 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 2019. 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: NSF will develop metrics and targets to monitor the progress of three initiatives relating to NSF's new Strategic Plan, new OPM or Administration initiatives, and/or NSF's Headquarters relocation.
Description	This goal captures NSF's commitment to two government-wide accountability processes, PortfolioStat and HRStat, which aim to ensure that decisions regarding resource investments are made through formal processes using evidence that involve decision makers from across the agency. Data regarding business need, cost, and risk-analysis will be provided. This data-driven approach to decision making promotes transparency and accountability. As directed in OMB M-12-10, "Implementing PortfolioStat", NSF has employed this tool to assess the maturity of its IT portfolio management process, make decisions on eliminating duplication, augment current 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.
Trend Information	Monitoring the IT investment portfolio and the implementation of HR Stat has been a performance goal since FY 2014.
Lead Organization/s	Offices of the Chief Information Officer and the Chief Human Capital Officer, Office of Information and Resource Management

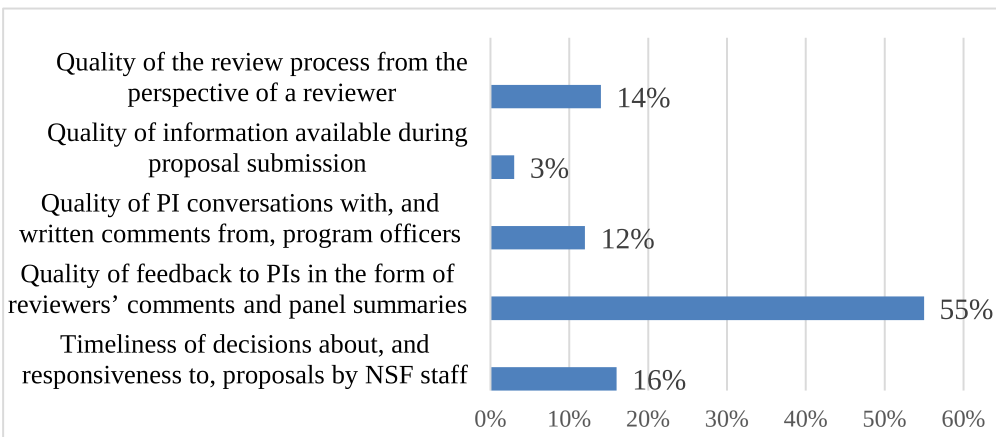
Goal 4: Make Timely Award Decisions

Goal Statement	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.
Indicator and Target Measure, Milestone, or Deliverable	75 percent.
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. An important issue 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 weaken the merit review process by forcing premature decisions. 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 require more time under review 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. 
Lead Organization/s	Office of Integrative Activities, Office of the Director Office of Budget, Finance, and Award Management

Goal 5: Improve Review Quality

<table>
<tr><td>Goal Statement</td><td>Improve the quality of written reviews of NSF proposals.</td></tr>
<tr><td>Indicator and Target Measure, Milestone, or Deliverable</td><td>By September 30, 2018,
1. 50 NSF programs will have held orientation sessions that include “Tips on how to write better reviews.”
2. 5000 reviewers of NSF proposals will have viewed “Tips on how to write better reviews” prior to preparing written reviews.</td></tr>
<tr><td>Description</td><td>This goal addresses feedback from a 2015 survey of people submitting proposals to NSF and those who review proposals. Survey respondents identified the quality of reviews as an important factor in improving their proposals and fostering science (see chart below). This goal also follows-through on analysis and input from other NSF planning activities: first, a strategic review in FY 2015 recommended that NSF use what was learned from the survey to inform a new performance goal aimed at improving customer service; second, Committees of Visitors (COVs), program officers, and principal investigators have frequently noted that the quality of individual written reviews were variable.

In the survey, proposers were asked “which of the following factors will have the most significant effect in fostering science?” The following chart shows the percentage of responses for each factor from 22,714 respondents.



The centerpiece of this goal is a pilot program, initiated in December 2016, to improve the quality of written reviews of NSF proposals. The pilot program encourages NSF programs to use early reviewer orientation via webinar to provide reviewers with information on how to write more effective reviews, along with instructions on conflicts of interest and other specific information about the program or solicitation. The webinar helps reviewers understand the review criteria and gives them an opportunity to ask questions they may have about the application of those criteria. The intention is to make written reviews more useful to both principal investigators and NSF program staff.

Outputs from the pilot program that NSF will track in FY 2018 include the number of NSF programs that adopt the webinar orientation sessions and the number of reviewers who have viewed the webinar.</td></tr>
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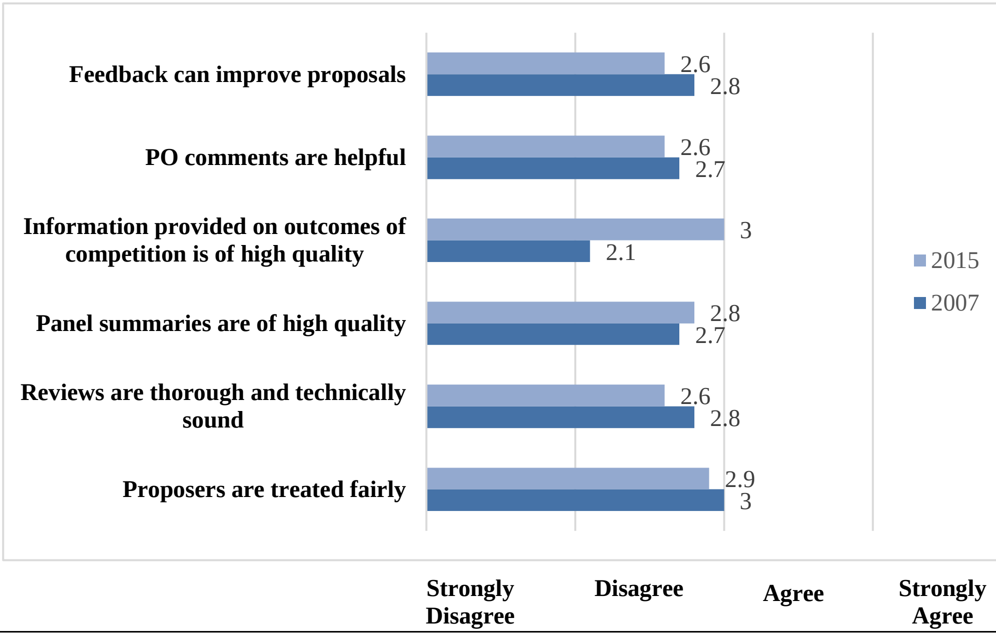
Trend Information	This is a new performance goal in FY 2018. Proposer surveys conducted in 2007 and 2015 informed this pilot. The chart below shows the average proposer perceptions of feedback received on NSF proposals. In FY 2019 NSF anticipates tracking the impact of the pilot program by surveying proposers again to learn whether the perceived quality of reviews increases. Note that the anticipated survey will take upwards of a year to field and analyze following the pilot program. 
Lead Organization/s	Office of Integrative Activities, Office of the Director

Goal 6: 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	1. By September 30, 2018, ODI will conduct the new IQ process with four organizational units. 2. Improve the four NSF organizational units' New IQ Self-Survey Scores by five 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) 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 is 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, with the expectation that when spread throughout the organization 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.

Description, continued	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.
Trend Information	NSF has had a performance goal relating to diversity and inclusion since FY 2011. Focusing specifically on inclusion represented a new direction for this goal in FY 2016 to reflect the priorities of current leaders at NSF and those of the federal and private sectors in general.
Lead Organization/s	Office of Diversity and Inclusion, Office of the Director

FY 2016 MANAGEMENT CHALLENGE PROGRESS REPORT

This section provides NSF's progress report highlighting the significant actions taken in FY 2016 on the management challenges identified by NSF's Inspector General at the beginning of that fiscal year.

Establishing Accountability over Large Cooperative Agreements
Lead Official: Branch Chief, Cooperative Support Branch, Division of Acquisitions and Cooperative Support, Office of Budget, Finance, and Award Management (BFA)

NSF Management Overview
The Office of Inspector General (OIG) challenge relates to NSF's oversight of large facilities construction awards. The Foundation currently utilizes end-to-end oversight policies and procedures to ensure adequate stewardship over federal funds for both construction and operations. These activities are carried out starting with the day-to-day oversight of the Science and Engineering Directorates and the Office of Budget Finance and Award Management (BFA) and extend through the decisional and governing responsibilities of the Office of the Director (O/D) and the National Science Board (NSB). The Major Research Equipment and Facility Construction (MREFC) Panel provides additional oversight of the design stage, which includes readiness for advancement and establishing the performance baseline for construction. Within BFA, the Large Facilities Office (LFO) develops policies and procedures related to large facilities, provides assistance to the program offices, and assures that policies, procedures, and good practices are being followed. Other BFA assurance units include the Cooperative Support Branch within the Division of Acquisition and Cooperative Support (DACS/CSB) and the Division of Institution and Award Support's Cost Analysis and Audit Resolution Branch (DIAS/CAAR) which supports cost analysis, award and post-award monitoring.

NSF has been continuously enhancing its pre-award and post-award oversight of large facilities cooperative agreements since June 2014. These enhancements are documented in the latest revision of the Large Facilities Manual (LFM) and internal Standard Operating Guidance (SOG). The December 2015 report of the National Academy of Public Administration (NAPA) supported NSF's use of cooperative agreements. However, the report also noted that NSF should equally emphasize increased internal management of the business practices critical to the enhanced oversight and project success in order to bring them into equal balance with the science and technical aspects of the project. NSF agrees with the spirit of all of the NAPA recommendations and plans to accommodate them in some form. One key step forward is that in March 2016, NSF completed the process for selecting a new managing organization for the NEON project, Battelle Memorial Institute. The turnaround of the NEON project reflects NSF's quick action to restore confidence in the oversight of the project and to ensure sound financial and technical oversight in bringing the construction portion of the project to completion.

Challenge 1
Establish accountability for the billions of federal funds in NSF's large cooperative agreements at the pre- and post-award stages and throughout the lifecycle of projects, and validate that the strengthened policies are implemented and working.

<u>Progress made in FY 2016</u>

- Implemented NAPA Recommendation 6.5: Hiring of two additional full-time equivalent (FTE) staff in LFO and making the LFO Head, a voting member on the MREFC Panel.
- Formed a Business and Operations Advisory Committee (BOAC) subcommittee on NAPA implementation. Specifically, the subcommittee is charged with providing options for appropriate agency-wide oversight for the NSF O/D by among other things, addressing two NAPA recommendations (Recommendations 6.2 and 6.4) dealing with: 1) the need for the NSF Director to have access to independent advice to serve as a sounding board for objective insight on large research

projects; and 2) a potential re-scoping of the role, duties, and membership of the MREFC Panel to include status update reviews of projects in the development and construction phases focusing on cost, schedule, and performance.

- Conducted a workshop with NSB to clarify roles and responsibilities with regard to large facilities oversight to address NAPA Recommendation 6.1 & 6.6: Clarifying oversight roles and use of annual NSF Facilities Plan, respectively.
- Implemented v1.0 of the NSB Facilities Portal as possible replacement to NSF Facilities Plan.
- Developed a certification, training, and core competency implementation plan for NSF staff engaged in large facilities oversight as part of the FY 2016 NSF Strategic Objective Review to address NAPA Recommendation 6.7: Project Management skill requirements.
- Drafted the joint LFO-DACS/CSB narrative for internal controls testing of enhanced policies and procedures related to large facilities oversight.
- Implemented appropriate/applicable enhanced oversight mechanisms currently used for construction awards on operational awards.
- Conducted Earned Value Management System (EVMS) verification/validation of the Large Synoptic Survey Telescope (LSST) project.

<u>Future Implementation Milestones</u>

- Develop and implement new SOG for conducting NSF EVMS verification/validation reviews.
- Develop new SOG on stage-gate and construction reviews to address NAPA Recommendation 6.3: Financial and project management expertise on panels.
- Develop new SOG on training, certification, and core competencies for NSF staff engaged in large facilities oversight.
- Complete EVMS verification/validation on Daniel K. Inouye Solar Telescope (DKIST) and Regional Class Research Vessel (RCRV) projects.
- Work with BFA's Division of Financial Management (DFM) under the Process Improvement Plan for the FY 2015 financial statement audit to test and evaluate new narrative and supporting procedures in accordance with OMB Circular, No A-123, "Management's Responsibility for Internal Control."

Challenge 2

Ensure that costs proposed for and incurred under its large facility projects, such as LSST and NEON, are fair and reasonable, and that the agency's cost surveillance practices are sufficient to identify: unallowable or unreasonable expenditures, funds spent for awards other than those for which they were provided, or potential cost overruns.

<u>Progress made in FY 2016</u>

- Implemented NAPA Recommendation 3.1: Exceptions to Cost Analysis (revisions to BFA SOG 2016-4).
- Implemented NAPA Recommendation 4.1: Retain control over a portion of budget contingency (BFA SOG 2016-2).
- Implemented NAPA Recommendation 4.2: Require Recipient use of U.S. Government Accountability Office (GAO) cost estimating and scheduling guides (LFM Section 4.2).
- Conducted detailed analysis on use of management fee to address NAPA Recommendation 4.3: Elimination of management fee.
- Implemented contract mechanisms to support independent cost estimate reviews (per GAO) for construction and operations.
- Implemented contract mechanism for incurred cost, accounting system and estimating system audits.
- Developed incurred cost submission tool for recipients specific to supporting incurred cost audits on cooperative agreements governed under the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (Uniform Guidance).
- Completed DKIST budget and schedule contingency review.

- Initiated Independent Cost Assessment (per GAO) of Antarctic Infrastructure Modernization for Science (AIMS) in support of the Preliminary Design Review planned for December 2016.
- Completed NSF cost analysis of the Battelle estimate to complete NEON construction, including Independent Cost Estimate (per GAO).
- Developed Corrective Action Plans (CAPs) for LSST and DKIST projects in response to OIG Alert Memos.

Future Implementation Milestones

- Provide analysis of options on use of management fee for NSF Leadership consideration in setting Foundation policy on management fee going forward.
- Develop and implement new SOG for selection of appropriate independent cost estimate review in accordance with the GAO Cost Estimating and Assessment Guide.

Management of NSF's Business Operations: Improper Payments
Lead Official: Division Director, Division of Financial Management, BFA

NSF Management Overview
In June 2015, the NSF OIG issued an audit report that found NSF non-compliant with the Improper Payments Elimination and Recovery Act (IPERA) for FY 2014. The OIG specified that NSF did not address all of the required OMB Circular A-123 Appendix C improper payment risk factors and that the quantitative portions of the risk assessment did not maintain statistical validity. The OIG recommended that NSF conduct a statistically valid sampling process in order to estimate an improper payments rate. NSF did not believe it was non-compliant with IPERA for FY 2014; nor did NSF agree to conduct additional IPERA statistical sampling. However, NSF did consider the results of the OIG report carefully and performed additional IPERA risk assessment work in FY 2015. Additionally, NSF conducted a series of meetings with the OIG and OMB in order to reach consensus with the OIG on NSF's efforts to insure compliance with IPERA.

Challenge
Develop an internal control process that provides reasonable assurance that payments are proper at the time they are made; and develop a sound process for assessing the agency's risk of improper payments.

<u>Progress made in FY 2016</u>
- Completed a process improvement plan, during October 2015, in response to the OIG IPERA audit report.
- Completed a qualitative improper payments risk assessment in December 2015 covering FY 2015.
- Received OIG-issued inspection report in May 2016, based on its review of the FY 2015 risk assessment, concluding that NSF is compliant with IPERA reporting requirements for FY 2015.
- Considered all areas for improvement in NSF's IPERA risk assessment process that had been identified in the OIG inspection report.
- Completed and submitted a CAP in July 2016 to address the audit findings from the OIG report. In August 2016, the OIG reviewed the CAP and found it responsive to their recommendations. All recommendations were resolved.
- Completed a policy and procedure document in September 2016 for future IPERA risk assessments (pursuant to the CAP).

<u>Future Implementation Milestones</u>
- Complete future IPERA risk assessments on a three-year cycle and report results in FY 2018.
- Consider award financial monitoring testing results as an input for the qualitative IPERA risk assessment.

Management of NSF's Business Operations: Information & IT Resources
Lead Official: Division Director, Division of Information Systems, Office of Information and Resource Management (OIRM)

NSF Management Overview
NSF is aware that the security posture of its information systems is of critical importance to NSF's ability to carry out its mission. The IT security program is evaluated yearly by an independent organization in accordance with the Federal Information Security Management Act (FISMA). NSF has been proactive in reviewing security controls and identifying areas to strengthen the program, including incorporation of information gained and lessons learned from the FISMA report. NSF ranks seventh out of the 24 CFO Act agencies in cybersecurity assessment scores in the most recent annual FISMA report to Congress.

Challenge
Allocate appropriate resources to correct IT security weaknesses, particularly relating to the U.S. Antarctic Program (USAP) and provide increased assurances of adequate protection; and develop and implement a robust information security continuous monitoring (ISCM) program that protects agency information and IT resources against increasing numbers of IT security threats.

Progress made in FY 2016
- US Antarctic Program (USAP)
  - USAP continued to allocate appropriate resources to the IT security program to address information security weaknesses identified in the annual FISMA review.
  - USAP improved the analysis of system scans to ensure configuration compliance and reviewed processes to ensure proper background investigations on all new hires.
  - NSF's Division of Polar Programs established a phased approach to address an improved continuity of operations capability.
- Information Security Continuous Monitoring (ISCM)
  - Initiated implementation of the Continuous Diagnostics and Mitigation (CDM) Phase 1. NSF will be the first federal agency to complete implementation of the CDM Phase 1 in Quarter 1 FY 2017.

Future Implementation Milestones
- USAP: Continue to address identified IT security weaknesses through program funding.
- ISCM: Utilize CDM Phase 1 products and services (focusing on tools implementation) to improve its automated continuous monitoring capability.

Management of NSF's Business Operations: Transparency & Accountability
Lead: Office of the Director

NSF Management Overview
NSF is well-positioned to successfully implement the Digital Accountability and Transparency (DATA) Act. The DATA Act is a government-wide initiative led by OMB and the U.S. Department of Treasury (Treasury) to standardize and publish the federal government's wide variety of reports and data compilations related to spending: financial management, payments, budget actions, procurement, and assistance. NSF senior agency officials were aware of the Act even prior to its enactment in April 2014. When the legislation passed, NSF moved immediately to leverage its resources to prepare for implementation. In October 2014, NSF designated a senior official in its Office of the Director (O/D) to serve as the agency's DATA Act Senior Accountable Official (SAO). The SAO identified subject matter experts in BFA and the Office of Information and Resource Management (OIRM) for implementation support and the group formed an internal governance structure that included an executive-level steering committee, a DATA Act Working Group (DAWG) and a DATA Act Project Management Office (PMO). Additionally, NSF engaged its OIG to facilitate collaboration around stewardship and in recognition of the OIG requirement to publish a DATA Act readiness review by November 2016, and OIG staff have regularly attended DAWG meetings.

Government-wide, NSF staff have represented the agency in connection with DATA Act-related activities, including the Financial Assistance Committee for E-government (FACE); the Data Standards Working Group, a volunteer subgroup of the FACE charged with performing analyses and making recommendations on issues of government-wide data standardization; the Procurement Committee for E-government; and numerous additional DATA Act-related workshops, meetings and small-group strategy sessions with OMB, Treasury, and other CFO Act agencies. These collaborations have been key to NSF's DATA Act implementation success.

NSF's DATA Act implementation has adhered to applicable DATA Act guidance issued by OMB and Treasury. In particular, implementation at NSF is guided by the government-wide DATA Act Implementation Playbook Version 2.0 that tracks the 8-Step Implementation Approach with implementation status reported via the associated OMB/Treasury Dashboard. NSF uses a phased iterative approach to update current processes for reporting procurement and financial assistance information to USASpending.gov using the Award Submission Portal (ASP), and has instituted new processes to produce and upload required account-level budget, spending, and award information. NSF leverages government-wide solutions and resources that are made available for implementation.

NSF is actively taking steps to mitigate risks or challenges and is employing multiple approaches to ensure on time compliance. No major system changes have been identified in order for NSF to meet the deadline. Going forward, to ensure adequate resources are available for a successful and on time implementation, the DAWG will continue to foster strong internal, executive-level and government-wide communication. NSF will also continue to communicate its challenges and needs to OMB and Treasury.

Challenge
Foster greater transparency over NSF spending through successful implementation of the Digital Accountability and Transparency Act (DATA Act) to make the necessary NSF system and process changes.

<u>Progress made in FY 2016</u>
- Performed inventory of agency data and associated business processes.
- Participated in government-wide effort to implement OMB Circular A-11 DATA Act requirements and successfully submitted NSF A-11 test files to the OMB MAX system.

- Participated in "sandbox" testing to test Treasury's DATA Act Broker, the tool it developed to check validity of federal agencies' uploaded files and provides ability for agencies to certify their data.
- Revised future state of NSF's daily, bi-monthly and quarterly reporting based on the Broker specifications and final technical guidance DATA Act Information Model Version 1.0 (DAIMS v1.0) released April 29, 2016.
- Submitted to OMB/Treasury NSF's update to the agency's August 28, 2015 DATA Act Implementation Plan to show progress to date, incorporated additional guidance provided by OMB/Treasury, and provided revised cost and timeline estimates. Also submitted implementation plan updates to other governmental entities, e.g. Congress, OIG.
- Implemented data extract changes in iTRAK, NSF's financial accounting system, as well as in NSF business applications.
- Developed a back-up approach to meeting DATA Act deadline to mitigate the risk of Oracle patches not being delivered in enough time for testing and implementation.
- Participated in DATA Act Broker beta testing.

Future Implementation Milestones

- Generate and test Award Submission Portal (ASP) data file per Treasury's new specifications.
- Comply with ASP submission requirements to USASpending.gov.
- Make changes to eJacket and iTRAK to accommodate the change in budget object class from 410100 (Personnel Mobility Program) to 118500 (IPA Salary and Fringe Benefits).
- Implement Oracle patch for award attributes (first of five anticipated patches) and modify award system interfaces with iTRAK to populate the following attributes: Procurement Instrument Identifier (PIID), Parent Award Identifier (PAID), Federal Award Identification Number (FAIN), and Unique Record Identifier (URI).
- Upload financial assistance and procurement files to populate the award attributes in iTRAK.
- Implement remaining Oracle patches and generate the files that will be required to submit to the Broker for subsequent public reporting of financial data [these files are: file A (Appropriations Account Data), B (Object Class and Program Activity Data) and C (Award Financial Data)].
- Generate files A, B, and C using the implemented Oracle patches.
- Perform Broker testing by uploading agency generated files A, B, and C.
- Perform Broker testing by extracting data for files D1 (Award and Awardee Attributes for Procurement), D2 (Award and Awardee Attributes for Financial Assistance), E (Additional Awardee Attributes), and F (Sub-award Attributes).
- Perform Broker testing in order to validate files A through F to facilitate certification of NSF's data.
- Implement the back-up approach, as needed, to generate files A, B, C, and reconciliation reports to mitigate the risk of not having the Oracle patches ready for the DATA Act compliance by May 2017.
- Achieve compliance with May 2017 DATA Act implementation deadline.

Management of NSF's Business Operations: Government Records
Lead Official: Division Director, Division of Administrative Services, OIRM

NSF Management Overview
In 2012, OMB and the National Archives and Records Administration (NARA) issued a directive, OMB Memorandum (M) 12-18, "Managing Government Records," consistent with a 2011 Presidential Memorandum, requiring federal agencies to reform the policies and practices for the management of records and provide a framework for the management of electronic records. GAO subsequently issued Report 15-339, dated May 14, 2015, titled, "Information Management: Additional Actions Are Needed to Meet Requirements of the Managing Government Records Directive."

NSF formulated a CAP in response to the GAO report and is on schedule to meet all the planned actions enumerated in the CAP.

Challenge
Respond to GAO's recommendations related to NSF's records management policies and practices, and comply with the National Archives and Records Administration's (NARA) 2012 directive to take specific reform actions by appointed dates.

Progress made in FY 2016
- Submitted a CAP in November 2015 in response to the GAO Report 15-339, "Information Management: Additional Actions Are Needed to Meet Requirements of the Managing Government Records Directive."
- Deployed the eRecords Awards Archival System in February 2016 for the documentation and management of permanent electronic grant records. Because grant records are one of the most critical types of agency records, this activity will constitute a significant component of NSF's plan for achieving full compliance with OMB M-12-18.

Future Implementation Milestones
- Formalize plans to manage other types of electronic records and make progress towards identifying the necessary revisions to current records management policy, technology requirements, and potential solutions.
- Ensure execution of the comprehensive plan and implementation strategy managing permanent records electronically.
- Formalize NSF plans to implement the Capstone approach, a government-wide approach for managing permanent and temporary e-mail records in an electronic format. OIRM will identify any necessary revisions to current records management policy; assess technology requirements and potential solutions; and develop the implementation strategy that will ensure NSF meets the December 31, 2016 deadline

Management of the Intergovernmental Personnel Act (IPA) Program
Lead Official: Deputy Division Director, Division of Human Resource Management, OIRM

NSF Management Overview
NSF provides the opportunity for scientists, engineers, and educators to rotate into the Foundation as temporary Program Directors, advisors, and leaders. Rotators bring fresh perspectives from across the country and across all fields of science and engineering supported by the Foundation, helping influence new directions for research in science, engineering, and education, including emerging interdisciplinary fields. Because NSF supports fundamental research at the frontiers of science and engineering, NSF relies on the synergy of federal employees and temporary staff for a constant infusion of new knowledge into the broad understanding of science, and a continuously improving structure of systematic and rigorous merit review.

In April 2016, NSF Director France A. Córdova announced the establishment of a Steering Committee for Policy and Oversight of the IPA Program (IPA Steering Committee). The Steering Committee serves as the primary body for considering policy on NSF's use of IPAs and oversees common approaches to budgeting and implementation of the IPA program.

Challenge 1
Examine the costs associated with NSF's rotator programs to ensure that federal funds entrusted to the agency are being spent effectively and efficiently.

<u>Progress made in FY 2016</u>
- Established IPA Steering Committee (detailed description set forth under Challenge 2).
- Submitted Steering Committee reports to Director Córdova in August 2016, which, among other things:
  - Summarized the Steering Committee's analysis of costs related to salaries, benefits (including relocation benefits), and individual research and development (IR/D) travel and benchmarking with other federal science agencies;
  - Recommended the development of an integrated agency-wide workforce framework to ensure that NSF maintains the optimal balance of federal employees and IPAs;
  - Identified strategic cost saving areas requiring additional stakeholder consultation, including institutional cost sharing; and
  - Identified strategic cost saving areas that could be examined concurrently with the development of an agency-wide framework.
- Documented plans for the IPA Steering Committee to serve as the lead to carry out NSF's commitment to review the overall IPA program and associated costs and benefits every four years and assess the impacts of actions taken to reduce IPA costs. This review and assessment is part of NSF's corrective action plan that responds to the OIG's Cost of IPAs audit.

<u>Future Implementation Milestones</u>
- Complete, via IPA Steering Committee task groups, a plan to establish an agency-wide workforce framework and recommendations for the potential use of new or additional hiring authorities in support of that framework.
- Ensure IR/D guidance (planned for implementation in FY 2017) supports the goal of combining IR/D with telework, where appropriate, to maximize the use of travel funds.
- Implement approved changes to NSF's policies for the reimbursement of IPA costs identified in OMB M-12-18.

Challenge 2
Establish and maintain strong oversight of NSF's Intergovernmental Personnel Act (IPA) program in order to provide continuity for programmatic leadership despite frequent turnover in executive positions, to

manage potential conflicts of interest in funding decisions, to promote transparency in funding decisions, and to ensure that IPAs and other rotators comply with federal laws after they leave NSF.

Progress made in FY 2016

- Established IPA Steering Committee with specific responsibilities to include championing the effective use of IPAs and the importance of addressing management risks; reviewing policies concerning IPA assignees, policies impacting IPA assignees, and policies where the use of IPAs may impact the implementation of those policies; reviewing data on IPAs to inform the Committee's oversight duties; coordinating the development of an NSF-wide budget for the IPA program; and providing guidance on methods for managing to the overall budget while ensuring a diverse, high quality cadre of IPAs.
    - As of September 30, 2016, the IPA Steering Committee met nine times and submitted one initial and two revised reports on managing IPA costs and developing an integrated workforce framework to Director Córdova.
    - The IPA Steering Committee developed strategic principles for management of the IPA program: community engagement, partnership, creativity, transparency, accountability, intentional balance in the workforce structure, and commitment to ongoing improvement.
- Continued identification and management of conflicts of interest related to IPAs:
    - Communicate standards of conduct—IPAs are subject to the same ethics rules as everyone else who works at NSF:
        - Standards of conduct are communicated in the IPA agreement.
        - New employees, including IPAs, attend new employee orientation and are briefed on the ethical obligations of Federal service.
        - IPAs file a financial disclosure report: all financial disclosure report filers, including IPAs, receive annual Conflict of Interest (COI) training. After filing a financial disclosure report, filers including IPAs receive a written reminder of the COI rules.
    - Track conflicts – Each COI official tracks conflicts in writing or through eJacket.
    - Ensure continued compliance with Federal laws after leaving NSF:
        - Employees, including IPAs, who are at or above the GS-12 salary level or equivalent, are required to attend a COI exit briefing by the Office of the General Counsel (OGC) Ethics Team explaining the post-employment ethics rules.
        - Former employees, including former IPAs, are encouraged to contact the Ethics Team even after they leave.
- Developed and piloted a one-day course, "Oversight of Merit Review for Division Leaders," to provide NSF Division Leaders, including IPAs, mission-critical information on their role in providing oversight of the NSF Merit Review process. Topics include: Overview of the Proposal & Award Process, Key Roles and Responsibilities in Merit Review, Role of Division Leadership in Ensuring Fairness of Review, How Program Officers Make Recommendations, The Review Analysis, and Understanding Recommendation Logistics and Award Abstracts.

Future Implementation Milestones

- The IPA Steering Committee will:
    - Review and update core policies relating to IPAs, as found in the NSF Personnel Manual, as needed;
    - Establish a framework for and review data on IPAs for oversight of management of the program;
    - Coordinate the development of an NSF-wide budget for the IPA program as part of the annual budget cycle; and
- Ensure that periodic data is provided to the directorates and offices on the completion of mandatory training and status of performance plans and appraisals.

Moving NSF Headquarters to a New Building
Lead Official: Senior Relocation Project Officer, OIRM

NSF Management Overview
NSF is well-positioned to begin occupying its new location in Alexandria, Virginia by August 2017. The NSF Relocation Office (NRO) is leading this effort and is charged with ensuring a successful outcome to NSF's expiring lease effort through the delivery of a next-generation NSF headquarters facility. NRO's mission is accomplished through input of the entire NSF staff through Directorate liaisons, the American Federation of Government Employees (AFGE) Union-Local 3403, the agency Relocation Executive Advisory Group (REAG), the General Services Administration (GSA) and other stakeholders to the project. Through demonstrated leadership and disciplined project management, NRO has made significant progress in key areas to ensure project success and to mitigate risks relating to scheduling delays, union negotiations and records management. NRO has also taken concrete steps to align the project's budget with its estimated cost.

The groundbreaking for the new NSF Headquarters was January 2014, construction on the interior space began in April 2016 and work will finish by August 2017. The new building will prominently reflect NSF's role nationally and internationally in the science and engineering community.

Challenge 1
Mitigate the risk of continued project delays associated with a revised relocation schedule that includes little slack time and two phases of union negotiations that still need to be completed.

<u>Progress made in FY 2016</u>

- Working with GSA, settled the owner's delay claim from $60 million down to $14.5 million and reset the project schedule.
- Finalized all design documents in accordance with the revised project schedule and without delay.
- Along with GSA, awarded a $70 million contract for tenant improvement construction.
- Brought on a full-time, professional project scheduler who developed an Integrated Project Schedule that identifies the project's critical path, assigns responsibility, and forms the basis for tracking progress.
- Ensured all procurements were awarded in accordance with the Integrated Project Schedule, including information technology, furniture, security, and audio-visual contracts.
- Managed FY 2016 relocation-related procurement activities; ensured that the FY 2016 and FY 2017 procurement and budget schedules supported and aligned with the projected relocation timeline.
- Added two project managers with office relocation experience to the NRO team.
- Hired a professional cost estimating and construction quality management firm to prepare detailed costs estimates for major submittals and requested change orders.
- Completed Phase 2 negotiations with AFGE Local 3403 without negatively impacting the project schedule.
- Started employee workspace selections in accordance with the Phase 2 union agreement and Integrated Project Schedule.
- Briefed senior leadership on value-engineering options, and drove decisions that control costs and provide a functional headquarters that helps NSF meet its mission.

<u>Future Implementation Milestones</u>

- Further develop the Integrated Project Schedule and continue to meet regularly with OIRM leadership to manage the project, monitor progress, mitigate risks, and allocate resources.
- Maintain bi-weekly procurement meetings with DACS to ensure all procurements are made without negatively impacting the project schedule.

- Complete the third phase of negotiations with AFGE Local 3403 without delaying the project schedule.
- Finalize employee workspace selections and order all furniture, fixtures, and equipment according to the project schedule.

Challenge 2
Plan for and manage the logistics of the actual move to the new headquarters building, including addressing the lack of a detailed master schedule, having to negotiate with the union on furniture and space issues, fewer opportunities for design review, less storage space, lack of a records schedule for destruction of documents and lack of a responsible project person with direct access to the Director.

<u>Progress made in FY 2016</u>

- Determined the strategy to move employees into the new building in accordance with the project schedule. Communicated plan with senior leadership, AFGE, and directorates.
- Engaged OIRM essential senior staff to centralize relocation planning and identify potential move-related cost-impacts.
- Determined phasing for the move based on current and new building constraints and other major move assumptions associated with IT, furniture, elevator, dock availability, etc.
- Hired two full-time contractors to gather and analyze key data impacting the move plan, as well as develop two relocation sequence options for leadership’s consideration.
- Announced to NSF staff the move sequence to Alexandria.

<u>Future Implementation Milestones</u>

- Key activities leading up to August 2017 relocation:
    - Develop detailed relocation plan.
    - Determine furniture for reuse and associated migration plan.
    - Develop furniture, fixtures and equipment decommissioning strategy.
    - Develop welcome guide/employee orientation requirements.
    - Establish new building protocols and policies.
    - Establish move communication program for end users.
    - Develop migration plan for division equipment.
    - Decommission existing facilities.

Management of the U.S. Antarctic Program
Lead Official: Division Director, Directorate for Geosciences, Division of Polar Programs

NSF Management Overview
Through the Division of Polar Programs (PLR) in the Directorate for Geosciences, NSF funds and manages the U.S. Antarctic Program (USAP), which supports United States' research and national policy goals in the Antarctic. Given the remote location, extreme environment, and the short period of time during which the continent is accessible, significant challenges exist for ensuring the availability of necessary logistics, operations, and science support. There are also unique and internationally-linked environmental, health, and safety issues present at the remote location. In exercising its management responsibilities, NSF relies on internal staff with the requisite expertise as well as a network of contracted support and federal agency partners. Periodically, the program is reviewed by external panels of experts.

Challenge 1
Establish and maintain a world-class scientific research program in Antarctica's remote and harsh environment.

<u>Progress made in FY 2016</u>
- Continued progress on the 2012 Blue Ribbon Panel (BRP) recommendations, including investment in prioritized lifecycle acquisitions and infrastructure upgrades.
- Addressed major infrastructure upgrades recommended by the BRP report for McMurdo Station through continued design efforts:
  - Continued designs of Core Facility and Utilities packages in preparation for the Antarctic Infrastructure Modernization for Science (AIMS) project MREFC Preliminary Design Review (PDR).
  - Initiated design efforts using NSF Research and Related Activities (R&RA) funds for upgrades to McMurdo lodging, Vehicle Equipment/Operations Center, Information Technology & Communications (IT&C) Primary Operations Center, and Palmer Pier replacement.

<u>Future Implementation Milestones</u>
- Complete necessary planning/design efforts for individual Antarctic Infrastructure Modernization for Science (AIMS) components.
- Complete designs for Palmer Pier, lodging, and IT&C Primary Operations Center.
- Prepare for AIMS External Panel Review.
- Complete planning/design for the Ross Island Earth Station (RIES).

Challenge 2
Control the cost of the USAP and ensure adequate oversight of payments to the USAP contractor.

<u>Progress made in FY 2016</u>
Continued to review and approve and/or adjust, as warranted, invoices to the USAP contractor. Prior to approval, invoice review is done by staff whose primary responsibility is review and resolution of invoiced amounts with the contracting officer and contracting officer's representative, a documented process initiated in FY 2013.

<u>Future Implementation Milestones</u>
Continue to monitor invoices from the USAP contractor in accordance with established procedures.

Challenge 3
Ensure the overall health and safety of all USAP participants.

Progress made in FY 2016

- Pharmacy System: Instituted internal controls to address OIG concerns related to potential drug allergies and interactions and provided assistance in getting information on prescribed drugs. A pharmacy technician was deployed to McMurdo Station during the 2015/16 operating season to review the current state of the pharmacy and its management. The pharmacy system was revitalized and repairs were made to the database that is currently in use.
- Law Enforcement: Achieved full compliance of NSF's law enforcement program with all U.S. Marshals Service requirements for certification and training, and recommendations for law enforcement tools made by the Service.
- Breathalyzer Unit Calibration: Procured breathalyzer units that do not require calibration. These units provide redundancy for the existing breathalyzer inventory.

Future Implementation Milestones

- Code of Conduct: Finalize a process for receiving and reviewing Code of Conduct violations.
- Pharmacy System: Identify a suitable system responsive to NSF's contractor's proposal to procure a new pharmacy system.
- Law Enforcement: Plan for a 2016/17 site visit to Antarctica, resources and schedules permitting. PLR has had internal conversations with OGC and will reach out to law enforcement organization contacts shortly. Post-site visit, expect to identify any desired changes and target implementation for the following season.
- Breathalyzer Testing Requirements: Continue to explore the advisability and feasibility of the OIG-recommended requirement for breathalyzer testing for all USAP participants. Consultations with the Department of Justice on policy and legal concerns are planned for FY 2016/17.

Improving Grant Administration
Lead Official: Deputy Division Director, Division of Institution and Award Support, BFA

NSF Management Overview
As of June 30, 2016, the NSF award portfolio consisted of 42,206 active awards, representing $28.2 billion in obligated funds to 2,873 unique awardees. NSF accountability efforts span six award stages (proposal submission, merit review, pre-award financial review, post-award monitoring, award closeout, and audit follow-up) to ensure financial capability and accomplishment, non-financial administrative and programmatic compliance, and research performance.

The foundation of NSF's accountability efforts is its suite of policy and procedural documents that incorporate federal regulations, legislative mandates, and Agency-specific requirements; the translation of policies and procedures into business rules that are enforced through NSF's information technology systems; and a risk-based approach to financial and administrative monitoring. Baseline monitoring activities, which are conducted on most awards through standard, recurring, and automated processes, focus on post-award administration and financial transactions in order to identify exceptions and potential issues that may require further scrutiny through advanced monitoring. The baseline monitoring efforts of DFM can reveal potential financial anomalies, inaccurate expenditure reporting, or evidence of a possible misunderstanding of, or non-compliance with, federal cash management requirements and/or NSF guidelines.

During FY 2016, NSF and the OIG agreed to expand the scope of their formal dialogue across activities that now span external audit resolution, large facilities, contracts, financial statement audit issues, as well as internal and performance audits. NSF continues to expand and upgrade mechanisms for communicating policies, procedures, and business practices within this dynamic environment to its staff and external stakeholder communities. In FY 2017, NSF will restructure its Cost Analysis and Audit Resolution Branch into two separate organizations (pre-award, post-award) to strengthen effectiveness of grants oversight to meet the growing need for deeper subject matter expertise, improved resource utilization, and strategic planning.

Challenge 1
Implement controls over spending of grant funds that ensure transparency and accountability without creating undue administrative impacts on awardees and federal program officers.

<u>Progress made in FY 2016</u>

- Coordinated inter-agency development and clearance of Research Terms & Conditions, which implement the Uniform Guidance issued by OMB. This effort creates greater consistency in the administration of Federal research awards and reduces awardee administrative burden by having one standardized set of terms and conditions to comply with, instead of disparate sets from each research agency. This also allows the Federal research agencies to manage awards in a similar fashion.
- Expanded integration of NSF's new financial and awardee payment process systems to further data transparency and decision-making, as well as to provide real-time cash transaction and funds control capabilities.
- Implemented baseline award monitoring of financial transactions to assess allowable costs associated with grant payments, utilizing statistically-based testing and NSF Risk Assessment results as stratification criteria to ensure coverage across the grant portfolio. This process improved transparency and accountability by enabling DFM to use a statistically based sample size that resulted in requiring fewer test samples, which subsequently reduced the burden on those grantees who must provide documentation to support the payments being tested.

- Initiated the development of a new baseline monitoring activity for financial transactions to review grants with high unliquidated balances and short remaining grant periods, which will be used to develop new baseline monitoring metrics.
- Converted Small Business Innovation Research (SBIR) Phase I grants (with start dates as of July 1, 2016) and SBIR Phase II grants (with start dates as of August 1, 2016) to the Award Cash Management Service (ACM$) to minimize manual processing and leverage ACM$ funds control capabilities, which will allow for improved transactional accuracy due to automating the process and for quicker, more expeditious processing of SBIR drawdowns for grantees.
- Implemented use of the Federal Awardee Performance and Integrity Information System to ensure transparency and accountability of performance in federal assistance awards.
- Continued to strengthen working relationships among NSF program officers, NSF grants and oversight officials, and the NSF OIG to address significant issues related to allowability, allocability, and reasonableness of funds expended in the conduct of research.

<u>Future Implementation Milestones</u>

- Refine, as necessary, and conduct FY 2017 baseline award monitoring of financial transactions across NSF's grant portfolio; explore feasibility of strengthening integration of baseline and advanced monitoring activities; initiate baseline monitoring review of grants with little or no financial activity.
- Continue to implement legislative requirements: (1) standardization and publishing of reports and data on federal spending under the DATA Act and (2) reporting NSF information on undispersed balances in grant awards expired more than two years under the Grant Oversight and New Efficiency (GONE) Act.

Challenge 2

Due to federal streamlining of written guidance for administering grants, ensure provision of consistent guidance that does not contradict previous responses or written policies.

<u>Progress made in FY 2016</u>

- Ensured continued alignment of advanced monitoring efforts with *OMB Uniform Guidance (UG),* as well as that of external websites, fact sheets, and other information provided to NSF awardees.
- Provided training to NSF program staff on major revisions to the *Proposal & Award Policies & Procedures Guide (PAPPG), Proposal & Award Manual (PAM),* and NSF grant conditions. To reach a broader audience, training was provided both in-person as well as with an increased virtual presence.
- Increased in-person training and outreach at conferences and workshops sponsored by research administration professional societies allowing for more effective, real-time interaction with the community; and continued virtual training opportunities such as the webcast of the NSF Grant Conference, which allowed for on-demand viewing of sessions covering proposal preparation, merit review, award management, the CAREER program, as well as updates to NSF policies and procedures.
- Expanded automated Proposal Compliance Validation (PCV) checks by ensuring that proposals submitted to NSF comply with requirements specified in the FY 2016 *Proposal & Award Policies & Procedures Guide* (Chapter II.C.2 of the GPG). The new system enhancements check the following requirements and may trigger either an error or warning message depending on the funding opportunity type:
    - Proposals must be received by 5 p.m. submitter's local time on the established deadline date.
    - Biographical Sketch(es) and Current and Pending Support files are required for each Senior Personnel associated with a proposal.
    - Biographical Sketch(es) can only be uploaded as a file, must not exceed two pages, and can no longer be entered as text.
- The goal of automated compliance checking is to reduce the administrative burden on the research community and NSF staff while ensuring fair and consistent treatment of submitted proposals. So far,

95% of proposals submitted via FastLane have been checked by PCV and submitted successfully to NSF in FY 2016. (Note: Special Post Docs, Award Supplements, and PI-Transfers are not included in PCV at this time.)

Future Implementation Milestones

- Continue to review internal guidance and procedures, and more aggressively use advanced monitoring and other outreach opportunities for NSF awardees to emphasize the importance of aligning their policies and procedures with the *UG*.
- Consolidate the external-facing *PAPPG* from a two-volume document comprising the *Grant Proposal Guide* and the *Award Administration Guide* into one concise document covering all NSF policies and procedures from pre-award through post-award and closeout.
- Consolidate the internal-facing *PAM* to provide NSF staff links to the *PAPPG* and *OMB Uniform Guidance*, providing access to a single, definitive source for federal policies and procedures.
- Continue to brief the research community and NSF staff on upcoming changes to NSF policy documents via in-person and virtual settings to maximize opportunities for dialogue and clarification, as well as on-demand reference information.
- Continue to expand use of PCV to ensure fair and consistent application of business rules while decreasing administrative burden on researchers, research administrators, and NSF staff.
- Continue multi-year project to upgrade NSF's Awards System, further enhancing the Agency's ability to enforce business rules consistently while streamlining internal processes.

Challenge 3

Due to OMB Uniform Guidance changes raising the Single Audit threshold from $500,000 to $750,000, take additional steps to oversee awardees that fall below the threshold.

Progress made in FY 2016

- Rather than diverting resources to address efforts deemed of lower risk to the federal government, continued to use an internal analysis of risk across the NSF portfolio as a basis for focusing advanced monitoring on awardees receiving between $2 million and $15 million in NSF funds. Additionally, prior to implementing the *Uniform Guidance,* OMB and the Council on Financial Assistance Reform (COFAR), in which NSF played an instrumental role, assessed that increasing the single-audit threshold by $250,000 (i.e., additional expenditures from any federal source) still allowed coverage of more than 99 percent of federal dollars awarded to more than 87 percent of federal grant recipients.
- Continued to fully implement the *Uniform Guidance* and to review, as applicable, all records that awardees are required to maintain for review by federal agencies, pass-through entities, and the Government Accounting Office throughout a broad array of pre- and post-award oversight efforts, especially advanced and baseline award monitoring activities.

Future Implementation Milestones

Assess and, as needed, refine criteria (i.e., award-specific, institutional, prior monitoring activities and results, award administration and program feedback) used in the annual NSF Risk Assessment in order to identify those awardees managing the highest risk portfolio, and targeting those institutions for advanced monitoring activities.

Challenge 4

Due to OMB Uniform Guidance changes to documentation requirements for labor effort reporting, reinforce with awardees the need to design and implement controls to reduce the risk of improper charges to awards and to provide a means to ensure the controls are achieving their objective.

Progress made in FY 2016

- Compared *Uniform Guidance* with prior OMB guidance, noting three major changes related to labor effort reporting: (1) removed examples of acceptable methods for charging and documenting labor effort to federal awards; (2) removed "suitable means of verification" language; and (3) emphasized development and adherence to strong internal controls by awardees. While awardees may use budget data to estimate reasonable approximation of the activity actually performed, their systems of internal controls must include processes to review interim, estimated charges. NSF believes the *Uniform Guidance* requirements are essentially identical to those cited under the previous "Planned Confirmation Methodology."
- Continued efforts to ensure that awardees comply with federal labor effort reporting requirements through feedback mechanisms resulting from oversight activities such as pre-award reviews, audit resolution, baseline and advanced monitoring, and post-award adjustment reviews.

Future Implementation Milestones

- Modify written internal guidance for performance of NSF oversight activities regarding policies and procedures for labor effort charges by award recipients (i.e., update Standing Operating Guidance to fully align with the *Uniform Guidance*).
- Refine, as necessary, and implement FY 2017 baseline award monitoring for the entire grant portfolio.

Challenge 5

Due to Uniform Guidance changes in the audit resolution process, offset the 30-day shortened timeframe for NSF by establishing a new accelerated process for identifying and tracking reports requiring resolution.

Progress made in FY 2016

- Analyzed 1,799 audit reports resolved between FY 2009 and FY 2016, noting that the large majority of reports were resolved in a timely manner. NSF does not foresee that the *Uniform Guidance* change poses a significant challenge to compliance with timeliness of resolution.
- Augmented Cost Analysis and Audit Resolution (CAAR) staff by two Cost Analysts to mitigate effects of workload in other priority areas, to aid in timely resolution of complex OIG audits.
- Modified the audit resolution module within CAAR's Monitoring and Tracking Database to track audit reports based on the date of their acceptance by the Federal Audit Clearinghouse (FAC) to set requisite six-month audit resolution target dates.

Future Implementation Milestones

- Accept OIG transfer of responsibility for, and develop procedures for, identifying and tracking single-audit reports submitted to the FAC requiring NSF resolution thus reducing the number of days between FAC acceptance and completed resolution.
- Continue to assess the effects of recent changes in policies/practices that have potential for impacting timeliness of audit resolution, including assumption of FAC drawdown responsibilities, increase of single-audit thresholds to $750,000 in federal expenditures, risk management, and potential opportunities for process streamlining.

Encouraging the Ethical Conduct of Research
Lead: Directorate for Social, Behavioral, and Economic Sciences

NSF Management Overview
The responsible and ethical conduct of research is critical to ensure excellence, as well as public trust, in science and engineering. In accordance with Section 7009 of the America COMPETES Act (ACA) (42 U.S.C. §1862o–1) and recognizing the importance of ethical conduct of research, NSF requires that each institution submitting a proposal certify, under penalty of perjury, that it has a plan to provide appropriate training and oversight in the ethical conduct of research to all undergraduates, graduate students, and postdoctoral researchers who will be supported by NSF to conduct research. The plan must be available for review upon request and to ensure compliance, NSF includes, as a term and condition of its awards, that institutions are responsible for verifying that undergraduate students, graduate students, and postdoctoral researchers supported by NSF to conduct research have received training in the responsible and ethical conduct of research. NSF's implementation of the Responsible Conduct of Research (RCR) requirement recognizes the breadth of research disciplines the Foundation funds, as well as the diversity of the educational levels of the individual researchers the agency supports, to ensure that the training will be effective and appropriately tailored. Specific training needs may vary depending on specific circumstances of research or the specific needs of students intending to pursue careers in basic or applied science after completing their education. Accordingly, it is the responsibility of each institution to determine both the content and the delivery method for the training that will meet the institution's specific needs. Furthermore, each institution must decide if development of content or pedagogical method is required, or if appropriate content and training can be provided from some existing sources or capabilities, and take appropriate action to implement their decisions.

NSF has taken concrete steps to enhance the awareness of ethical conduct of research issues by NSF staff, as well as the U.S. and international scientific research and education communities, by supporting the development of tools and resources to enhance the ability of research institutions to cultivate cultures of academic and research integrity. Most notably, the Online Ethics Center (OEC) provides resources, including an Ethics Education Library that institutions can use to deliver effective training that is tailored to meet the needs of their particular project. NSF's program: Cultivating Cultures for Ethical STEM (CCE STEM) invests in innovative approaches to enhance research into ethical conduct of research issues that can build the capacity of institutions to develop appropriate ethical conduct of research plans as required by the America COMPETES Act. NSF is committed to heighten the U.S. and international STEM community's awareness of these resources.

Challenge
Provide more oversight on institutional implementation of Responsible Conduct of Research (RCR) requirements and provide meaningful guidance regarding RCR training.

<u>Progress made in FY 2016</u>
- Continued to support research that provides answers to questions about creating responsible research communities.
- Continued to share state-of-the-art understanding of what approaches are most effective in outreach opportunities with NSF staff, and with U.S. and international scientific research and education communities.
- Identified and developed funding mechanisms to support reproducible and reliable science.
- Funded a major relaunch of the Online Ethics Center (OEC) website in February 2016, representing a significant expansion of resources and site functionality to include all of the sciences NSF supports. OEC is an NSF-funded initiative to serve those who promote learning and advance understanding of responsible research and practice in engineering and science. It provides online resources to engineers,

scientists, faculty, and students to understand and address ethically significant issues that arise in scientific and engineering practice and from the developments of science and engineering.
- Funded the workshop, "Enhancing Robust and Generalizable Experimental Behavioral Science" at Arizona State University. The goal of the workshop is to conduct a systematic analysis of disincentives undermining diversity and incentive structures supporting convenience and inertia over good science practices. An action plan will be developed for addressing and ameliorating these issues through more specific guidance for researchers.
- Hosted an RCR workshop at NSF in April 2016 for NSF program officers and other community members. The workshop highlighted the impact of NSF's policy on RCR training, along with best practices. Experts from federal agencies, the National Academies of Science, and universities discussed graduate and post-doc training, RCR challenges, RCR strategies, and RCR successes.

Future Implementation Milestones
- Continue to support and share research that provides answers to questions about creating responsible research communities, robust and reliable science, and best practices for ethical STEM.
- Outcomes of the Arizona State University workshop will include structured guidance for addressing the well-documented sampling bias that will contribute to broadening the sampling protocols for experimental behavioral science research.
- CCE-STEM program activities include funding a workshop on "Qualitative Research Ethics in the Big-Data"; an institutional transformation grant at the Georgia Institute of Technology titled, "The Role of Service Learning and Community Engagement on the Ethical Development of STEM Students and Campus Culture"; and five grants covering research projects in ethical maturity, ethical practice and responsible conduct of research in STEM.
- Issue an NSF Dear Colleague Letter (DCL) emphasizing the importance of the responsible and ethical conduct of research, and highlighting the availability of NSF-funded tools and resources on which institutions can rely in developing their required RCR plans. The DCL will also showcase NSF-funded research and workshops in this area.

LOWER-PRIORITY PROGRAMS

NSF's FY 2018 Request follows a thorough examination of programs and investments across NSF to determine where the potential exists for more innovative investments. This Budget Request includes nine proposed terminations, consisting of activities that have either achieved their goals or of activities that will be realigned to better serve the agency's mission. The total reduction is largely being redeployed into ongoing programs.

Program Terminations

Catalyzing New International Collaborations (CNIC) (-$190,000) supports the participation of U.S.-based researchers and students in activities intended to catalyze new international research collaborations. In FY 2018, the CNIC program will sunset because it achieved its stated goal. Lessons learned from CNIC will be incorporated in the revised International Research Experiences for Students (IRES) solicitation to support larger numbers of principal investigators and build collaborations at the disciplinary program level.

International Research Fellowship Program (IRFP) (-$2.32 million) introduced scientists and engineers in the early stages of their careers to international collaborative research opportunities, thereby furthering their research capacity and global perspective and forging long-term relationships with scientists, technologists, and engineers abroad. In FY 2018, the program will sunset because it achieved its objective. Lessons learned from IRFP will be incorporated into future program solicitations that support U.S. scientists, engineers, and students engaged in international research and education activities in all NSF-supported disciplines.

NSF Headquarters Relocation (-$38.87 million) funds will be greatly reduced, as the move will be substantially complete by the end of FY 2017. NSF is anticipated to complete the move of its headquarters to the new building in Alexandria, VA by October 1, 2017. A small budget remains in FY 2018 for items such as decommissioning of the current headquarters buildings and unanticipated changes required at the new headquarters.

Pan-American Advanced Studies Institutes (PASI) (no change) was a jointly supported initiative between the Department of Energy and NSF that supported short courses at the advanced graduate, post-doctoral, and junior faculty levels. PASI was paused in FY 2014, and will sunset in FY 2018, as assessments of the program indicate that it has reached its stated goals.

Science Across Virtual Institutes (SAVI) (-$50,000) fostered and strengthened interaction among scientists, engineers and educators around the globe, based on the knowledge that excellence in STEM research and education exists in many parts of the world and that scientific advances can be accelerated by scientists and engineers working together across international borders. The program achieved its stated goal and will sunset in FY 2018. Lessons learned from SAVI will be incorporated into future OISE program solicitations.

Science and Technology for America's Recovery: Measuring the Effect of Research on Innovation, Competiveness, and Science (STAR METRICS) (-$1.0 million) sought to provide a common empirical data and analytic infrastructure for recipients of federal research and development (R&D) funding to facilitate the sharing of data, interpretation of results, and to understand how federal funding for R&D affect the innovation ecosystem. As of January 1, 2016, STAR METRICS halted the federal collection of institution data and subsequent production of reports that help document the value of the federal government's investments in research and development. Because data collection has ended, the pilot activity has been completed.

Sunsetting NSF-wide Investments Returning to Core Programs

Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) (-$181.67 million) is a multi-directorate NSF-wide priority area that was established in FY 2011 to foster the necessary research, education, and infrastructure activities that would enable the achievement of a comprehensive cyberinfrastructure, leveraging existing data, software, and high-performance computing programs. Led by the Office of Advanced Cyberinfrastructure (OAC) within the Directorate for Computer and Information Science and Engineering (CISE), CIF21 was a partnership among the Directorates for Biological Sciences (BIO), CISE, Education and Human Resources (EHR), Engineering (ENG), Geosciences (GEO), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE). Following the scheduled sunsetting of CIF21 in FY 2017, NSF will transition some existing CIF21 activities as it continues to develop a focused set of activities in alignment with the National Strategic Computing Initiative (NSCI). In addition, the rich topic of data, encompassing data science, data management, data policy, community building, and workforce development, will also remain a strategic focus for NSF through the Harnessing the Data Revolution Big Idea, which will span research, education, and research infrastructure.

Research at the Interface of Biological, Mathematical and Physical Sciences (BioMaPS) (-$35.07 million) has sought to discover fundamental new knowledge at the intersections of the biological, mathematical and physical sciences, and engineering in order to enable innovation in national priorities such as clean energy, climate science, advanced manufacturing, and understanding the brain, which are essential to the Nation's prosperity, economic competitiveness, and quality of life. BioMaPS began in FY 2011 as a partnership between BIO and MPS. The program was expanded in FY 2012 with additional participation from ENG. The program is being eliminated as it has achieved its goal, leading to a culture change within NSF with cross-directorate collaboration in these fields having become standard practice. In FY 2018, only remaining continuing grant increments will be supported.

Science, Engineering, and Education for Sustainability (SEES) (-$103.63 million) was a coordinated effort to support research spanning a wide range of scientific domains that began in FY 2010. Multiple perspectives and areas of expertise were supported to increase the understanding of integrated systems of human society and the natural world and to lead the development of solutions to sustainability challenges. SEES was a multi-directorate program that included contributions from BIO, CISE, EHR, ENG, GEO, MPS, the Office of Integrative Activities (IA), the Office of International Science and Engineering (OISE), and SBE. Although FY 2017 concludes funding for the portfolio of SEES activities, NSF will continue investing in the research necessary for a sustainable human future, via other programs and mechanisms, such as hazards-related research projects under NSF's Risk and Resilience investment area, research through INFEWS, and other NSF core programs.

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.

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.[2]

In FY 2016, six directorates and offices convened nine COVs, covering all or part of nine divisions and one cross-cutting program. A list of the COVs performed is provided on the next page. The chapters of the directorates also contain information on these COVs, as well as information on *ad hoc* reports.

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 2016 follows. For more details about how the results of these specific evaluations are being used to shape agency decisions, see the chapter of the sponsoring directorate. Directorate chapters also contain a list of selected high-impact events (workshops, symposia, or other meetings resulting in publications) that inform their decision-making. For more information about program evaluation and collection and management of NSF programmatic data, see the Office of Integrative Activities chapter's section on NSF's Evaluation and Assessment Capability.

External Evaluations Completed in FY 2016

DIR	**Program, Topic, or Area Evaluated**	**Name of Evaluation**	**Evaluator**	**Link to report**
CISE	CEMMS and SaTC	Feasibility Evaluations	Science and Technology Policy Institute	Not available
CISE	Advanced computing infrastructure	Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science in 2017-2020	National Academies	www.nap.edu/catalog/21886
MPS	Astronomy	Review of Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics	National Academies	www.nap.edu/catalog/23560

[2] www.nsf.gov/od/oia/activities/cov/covs.jsp

List of Committees of Visitors Meetings, FY 2014-FY 2017

DIR	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018 (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	-	Human Resource Development EHR Core Research Undergraduate Education: TUES, STEP, WIDER, IUSE: EHR	Graduate Education Undergraduate Education: ATE, IUSE: EHR, S-STEM, Noyce
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

DIR	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018 (planned)
GEO (including OPP)	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: Atmosphere Section Polar Programs: Antarctic Sciences and Arctic Sciences Sections	Atmospheric and Geospace Sciences: programs TBD Earth Sciences: programs TBD	Atmospheric and Geospace Sciences: programs TBD Ocean Sciences: programs TBD
MPS	-	Astronomy Materials Research Physics	Chemistry Mathematical Sciences	-	Physics
SBE	-	Office of Multidisciplinary Activities Behavioral and Cognitive Sciences	Social and Economic Sciences	-	-
OIA and OISE	International Science and Engineering	Experimental Program to Stimulate Competitive Research (EPSCoR)	Major Research Infrastructure	-	International Science and Engineering

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."[3] NSF will continue this process in FY 2017 and FY 2018.

In FY 2016, 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 2016 report concluded:

> Based on the Fiscal Year (FY) 2016 Full Year 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 eight of NSF's nine annual performance goals. NSF was not able to complete the remaining goal in FY 2016 because the survey instrument was not available; IBM confirms that NSF did not achieve the goal.
>
> 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.

[3] 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.

[4] IBM Global Business Services, *National Science Foundation Performance Measurement Verification and Validation Report, Fiscal Year 2016 Full Year Report*. October 21, 2016.

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

FY 2016 ANNUAL PERFORMANCE REPORT

In FY 2016, NSF tracked progress toward its three strategic goals using nine performance goals, two of which were Agency Priority Goals (APGs). Six of the nine goals fully achieved their targets in FY 2016 and three did not achieve one or more targets. Below is a tabular overview.

Goal ID	Performance Goal	FY 2016 Result
1	APG: Improve Graduate Student Preparedness	Achieved
2	APG: Invest Strategically in Public Participation in STEM Research	Achieved
3	Ensure that Key Program Investments are on Track	Achieved
4	Ensure that Research Infrastructure Investments are on Track	Not Achieved
5	Use Evidence to Guide Management Decisions	Achieved
6	Make Timely Award Decisions	Achieved
7	Foster a Culture of Inclusion	Not Achieved
8	Evaluate NSF Investments	Achieved
9	Increase the Percentage of Panelists Participating in Merit Review Virtually	Not Achieved

Multiple years of trend data are available for NSF's quantitative performance measures (Goals 4, 6, and 9). Other performance goals monitor progress towards multiyear goals, such as implementation of a new process (Goals 7 and 8) or monitoring of strategically important investments (Goals 1, 2, 3, and 5).

<u>Goal 1: Improve Graduate Student Preparedness (Agency Priority Goal)</u>
Lead Organizations: Directorate for Geosciences, Directorate for Engineering.

Goal Statement
Improve STEM graduate student preparedness for entering the workforce.

Measure, Milestone, or Deliverable

FY	Target	FY 2016 Result
2016-2017	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.	Supplements = 80 Summer Institutes = 1
Trend Information		
This is a new goal in FY 2016. The topic was identified through the 2015 Strategic Review process.		

Discussion
A strong global economy relies on the ability to capitalize on technical innovations that result from a skilled and agile STEM workforce. To achieve this, 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. 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.

The purpose of this APG is to provide opportunities for science and engineering doctoral students to acquire the knowledge, experience, and skills needed for highly productive careers, inside and outside of academe. To achieve this goal, NSF is taking two approaches: piloting support for summer institutes, to provide students with broad experiences in professional development areas, and supporting supplements to existing research awards, to enhance graduate education opportunities.

In the first year of this APG, NSF supported 80 supplements, exceeding its two-year goal to fund 75 supplements. NSF will continue to support supplements in year two of the goal. NSF also requested proposals for summer institutes. One award was made, with more anticipated in year two.

Goal 2: Invest Strategically in Public Participation in STEM Research (PPSR) (Agency Priority Goal)
Lead Organizations: Directorate for Computer and Information Sciences and Engineering, Directorate for Education and Human Resources.

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).

Measure, Milestone, or Deliverable

FY	Target	FY 2016 Result
2016-2017	By September 30, 2017, NSF will implement mechanisms to expand and deepen the engagement of the public in research.	EAGERs = 26 Supplements = 5
Trend Information		
This is a new goal in FY 2016. The topic was identified through the 2015 Strategic Review process.		

Discussion
Scientists, mathematicians, and engineers have involved the public in their research efforts to solve challenging problems for centuries. These types of activities have been referred to in a variety of ways. For this goal, 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. Economic, societal, and technological trends are increasing the variety and value of what PPSR can accomplish. PPSR approaches can address new research questions and contribute to ongoing STEM research.

To achieve this APG, NSF will use three specific mechanisms to fund proposals that explicitly include PPSR approaches:

1. Early-concept Grants for Exploratory Research (EAGERs) are designed as "high risk-high payoff" awards with the potential to quickly further our understanding of how PPSR is leveraged to support scientific discovery and the public's engagement with research.
2. Supplements to existing awards provide opportunities (1) to 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.
3. Research Coordination Networks support communication and coordination across disciplinary, organizational, institutional, and geographic boundaries.

In the first year of this APG, NSF issued two Dear Colleague Letters to solicit EAGERs and supplements that include PPSR, and funded 26 EAGERs and five supplements. NSF also conferred and participated with other federal agencies in the Federal Community of Practice for Citizen Science and Crowdsourcing meetings.

<u>Goal 3: Ensure that Key Program Investments are on Track</u>
Lead Organization: Office of Budget, Finance, and Award Management.

Goal Statement
Ensure that key NSF-wide program investments are implemented and on track.

Measure, Milestone, or Deliverable

FY	Target	Result
2016	Monitor the progress of the following NSF-wide investments using a common set of milestones and indicators: NSF INCLUDES, INFEWS, and UtB.	Achieved
Trend Information		
2015	Monitor the progress of Cognitive Science & Neuroscience, CEMMSS, CIF21, SaTC, and SEES using a common set of milestones and indicators.	Achieved
2014	Monitor the progress of CEMMSS, CIF21, I-Corps™, INSPIRE, SaTC, and SEES using a common set of milestones and indicators.	Not achieved (4 of 6 monitored)
2011-2013	New goal in FY 2014	

Discussion
NSF instituted this 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 the NSF-Wide Investments chapter of its Budget Request to Congress. Although the overall impact of these investments will not be realized for many years, tracking near-term indicators of implementation and progress can help the agency make formative changes or course corrections.

In FY 2016, NSF successfully monitored the progress of three NSF-wide investments (NSF INCLUDES, INFEWS, and Understanding the Brain) 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 vitality and potential success, as they address 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 2016:
- Input indicator: progress towards the investment's funding level target.
- Output indicators: solicitations issued, proposals received, awards made.
- Program-specific activities: e.g. PI meetings, workshops, and/or 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.

<u>Goal 4: Ensure that Research Infrastructure Investments are on Track</u>
Lead Organization: Large Facilities Office, Office of Budget, Finance, and Award Management.

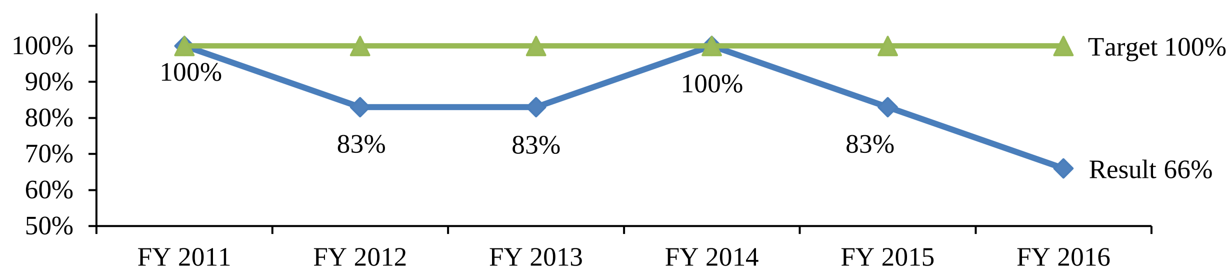
Goal Statement
Ensure program integrity and responsible stewardship of major research facilities and infrastructure.

Measure, Milestone, or Deliverable

FY	Target	Result
2016	Construction Project Monitoring: For all MREFC facilities under construction that are over 10 percent complete, keep negative cost and schedule variance at or below 10 percent.	Not achieved (2 of 3 projects were within cost and schedule variances)

Trend Information

Construction Project Monitoring Performance Trends, FY 2011-2016



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.

Two of the three projects that were over ten percent complete by the end of FY 2016 were on track. At the end of FY 2016, the Daniel K. Inouye Solar Telescope (DKIST) was 71 percent complete and the Large Synoptic Survey Telescope (LSST) was 33 percent complete. Both projects had cost and schedule variances well below the ten percent thresholds.

<u>Explanation of Unmet Goal</u>
The FY 2016 goal was not met because of cost and schedule issues associated with the National Ecological Observatory Network (NEON). These are discussed further in the NEON section of the MREFC Chapter of this Request.

<u>Goal 5: Use Evidence to Guide Management Decisions</u>
Lead Organization: Office of Information and Resource Management

Goal Statement
Use evidence-based reviews to guide management investments.

Measure, Milestone, or Deliverable

FY	Targets	Result
2016	HRStat 1. Establish indicators to assess progress of three workforce initiatives designed to meet the objectives of the Opportunities for Action in NSF's FY 2014 Strategic Review for Strategic Goal 3, Objective 1. 2. During FY 2016, focus at least two evidence-based reviews on the three identified workforce initiatives. PortfolioStat 3. NSF's information technology (IT) governance boards will evaluate and prioritize proposed investments for FY 2018. 4. NSF's IT governance boards will use cost and schedule data for ongoing investments to inform investment decisions for FY 2018.	All targets achieved
Trend Information		
2015	HRStat: 2 targets[5] PortfolioStat: 2 targets[1]	All targets achieved
2014	HRStat: 2 targets[1] PortfolioStat: 2 targets[1]	All targets achieved
2011-2013	New goal in FY 2014	

Discussion
HRStat and PortfolioStat are processes in which agency leaders conduct regular data-driven reviews of human resources and IT portfolio information. HR Stat targets focus on development and refinement of a human capital management dashboard for senior management use, and on the reporting of those data to management in formal meetings. Portfolio Stat targets monitor NSF's IT investment evaluation process.

<u>HR Stat</u>
In fulfillment of Target 1, the Strategic Human Capital Management dashboard was updated in FY 2016 to provide additional data about priority initiatives in the focus areas of employee engagement, recruitment and retention, diversity and inclusion, and workload. Consistent with the FY 2014 Strategic Review, NSF set a goal of retaining 70 percent of its permanent workforce onboard at the end of FY 2015 through the headquarters relocation at the end of FY 2017. The retention rate for that population is 90 percent through the end of FY 2016. HRStat meetings in Q1, Q2, and Q4 satisfied Target 2 in FY 2016.

<u>Portfolio Stat</u>
NSF's IT governance bodies (the Enterprise Architecture Working Group, Capital Planning and Investment Control Working Group, and the IT Resources Board) prepared the FY 2018 IT budget request and prioritized the IT investment portfolio. To inform their investment decisions, cost and schedule data were presented to the governing bodies throughout the course of the fiscal year. Major investments reviewed included Enterprise BI, Public Access, and Proposal Management Efficiencies.

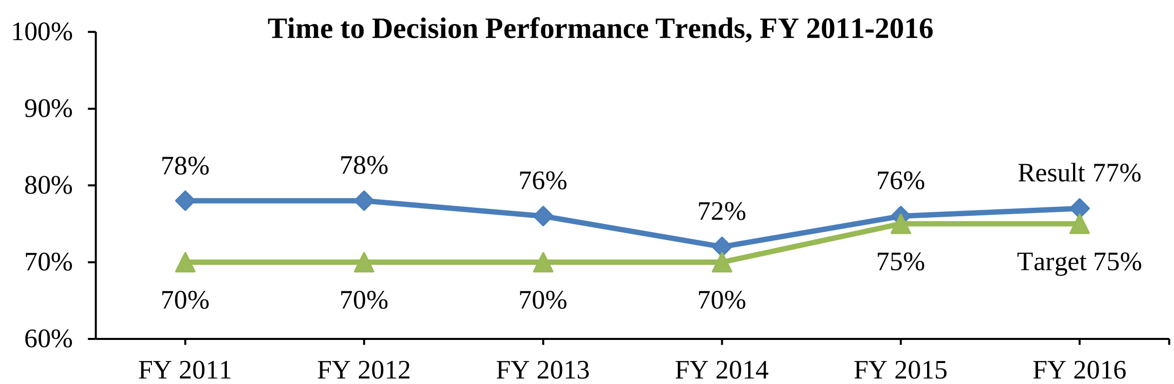
[5] For the full target language from previous years, please refer to the FY 2015 Performance Report in the FY 2017 NSF Budget Request (nsf.gov/about/budget/fy2017/pdf/56_fy2017.pdf).

<u>Goal 6: Make Timely Award Decisions</u>
Lead Organization: Office of Integrative Activities.

Goal Statement
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.

Measure, Milestone, or Deliverable

FY	Target	Result
2016	75 percent.	Achieved. Result = 77 percent.
Trend Information		



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 weaken the merit review process by forcing premature decisions. 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 merit review system.

Goal Change History
In FY 2015, this target was raised from 70 percent to 75 percent to be more in line with the historical trend of achievement at or above this level. The exception of FY 2014, in which NSF exceeded the 70 percent target by a historically low margin, was likely due to Foundation-wide delays in proposal processing after the lapse in funding authority in October 2013. The FY 2016 result of 77 percent was in line with historical achievement levels.

Goal 7: Foster a Culture of Inclusion
Lead Organization: Office of Diversity and Inclusion (ODI), Office of the Director.

Goal Statement
Foster a culture of inclusion through change management efforts resulting in change leadership and accountability[6].

Measure, Milestone, or Deliverable

FY	Target	Result
2016	1. By September 30, 2016, ODI will conduct the new IQ process with two NSF organizational units. 2. Improve the two NSF organizational units' New IQ Self-Survey Scores by five percent above established baseline.	No targets achieved
Trend Information		
2015	Attain six of six essential elements of a model EEO agency, perform two compliance desk reviews under antidiscrimination laws.	Not Achieved (4/6 elements, 2 desk reviews)
2014	Attain six of six essential elements of a model EEO agency, perform two compliance desk reviews under antidiscrimination laws.	Not Achieved (5/6 elements, 0 desk reviews)
2013	Attain five of six essential elements of a model EEO agency.	Achieved
2012	Attain four of six essential elements of a model EEO agency.	Achieved
2011	Attain three elements of a model EEO agency.	Achieved

Discussion
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 measure and drive inclusive intelligence in the federal workplace. Inclusive intelligence is defined as intentional, deliberate, and proactive acts that ensure that people feel they belong and are uniquely valued.

OPM has recently developed a process to supplement use of the New IQ by using change management tools to help agencies support diversity and inclusion more fully. 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. NSF has realized slippage in its FEVS inclusion-related results over several years, and recognizes that having a workforce comprised of a mix of permanent and temporary rotator staff requires targeted efforts. 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 habits throughout the Foundation.

<u>Explanation of Unmet Goal</u>
NSF's plan to choose two divisions in which to implement the New IQ in FY 2016 was delayed due to staffing transitions at NSF and delays in administration of the New IQ pulse (interim) survey.

[6] NSF has had a performance goal relating to diversity and inclusion since FY 2011. Former goals were largely focused on NSF's efforts to attain "Model EEO Agency" status. For information on earlier versions of this goal, including full goal language, refer to the FY 2015 Performance Report in the FY 2017 NSF Budget Request (nsf.gov/about/budget/fy2017/pdf/56_fy2017.pdf).

<u>Goal 8: Evaluate NSF Investments</u>
Lead Organization: Office of Integrative Activities.

Goal Statement
Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.

Measure, Milestone, or Deliverable

FY	Target	Result
2016	By September 30, 2016, NSF will have developed three illustrative models of evaluation frameworks 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.	All targets achieved
Trend Information		
2015	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.	No targets achieved
2011-2014	New goal in FY 2015	

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.

In FY 2016, EAC developed plans for continuous program and portfolio improvement, targeted to activities carried out in three key areas of NSF investment.

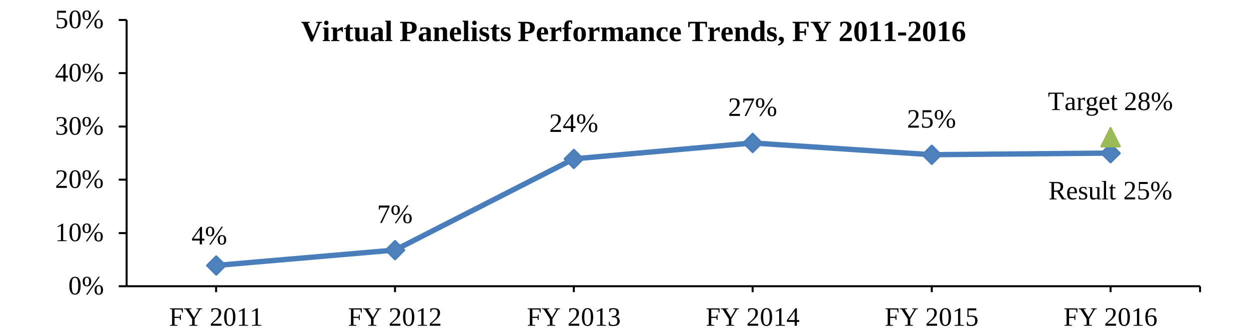
1. <u>Human Capital</u>: The statement of work for a contract awarded to monitor Research Experience for Undergraduates (REU) students articulates the criteria for what constitutes evidence for evaluating the REU program. It proposes a variety of methods that could be employed to generate such evidence and how they might be used to assess success.
2. <u>NSF-wide priorities</u>: As of the end of FY 2016, a contract was underway that builds upon a preliminary report on the feasibility of an evaluation of the Secure and Trustworthy Cyberspace (SaTC) program. The preliminary report establishes the evaluation framework to be used for the evaluation.
3. <u>Long-term strategic investments</u>: A contract to conduct an evaluation of the I-Corps program is underway. The research questions, design, and methods for obtaining and using evidence are discussed in the description of the evaluation framework developed by the contractor.

Goal 9: Increase the Percentage of Panelists Participating in Merit Review Virtually
Lead Organization: Office of Integrative Activities, Office of the Director.

Goal Statement
Increase the percentage of proposal review panelists that participate virtually while maintaining the quality of the merit review process.

Measure, Milestone, or Deliverable

FY	Target	Result
2016	By September 30, 2016, at least 28 percent of merit review panelists will participate virtually.	Not achieved. Result = 25 percent.
Trend Information		



Discussion
NSF makes extensive use of panels of reviewers to evaluate proposals, holding around 1900 panels annually. Review panels provide ample opportunity to test new methods and practices. One such practice, the use of virtual meeting technology to supplement or replace in-person panels[7], was piloted at NSF from the early 2010s under the assumption that face-to-face panels impose a significant time burden on reviewers. NSF has had a performance goal relating to virtual panel usage since FY 2012[8]. Usage of virtual panelists peaked in FYs 2013 and 2014 due to several factors: a response to reductions in travel budgets; development of training materials; and management's encouragement to utilize virtual panels as a viable reviewer participation mechanism. However, in that time period and subsequently, surveys have consistently shown higher satisfaction ratings with in-person participation on the part of reviewers and NSF staff.

Explanation of Unmet Goal
The 28 percent target was a "stretch" level and not in line with projections for likely FY 2016 virtual panelist usage. Setting a stretch goal did not play a role in driving performance in this area.

[7] The term "virtual panelist" refers to a panel reviewer who does not travel to a common location but instead participates via teleconference, videoconference, or an online meeting technology.
[8] For four years, the goal tracked a pilot project that measured the number of "wholly virtual" panels, i.e. panels that used only virtual panelists. For more information about earlier versions of this goal, refer to the FY 2015 Annual Performance Report in the FY 2017 NSF Budget Request (nsf.gov/about/budget/fy2017/pdf/56_fy2017.pdf).

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FY 2018 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; $5,361,650,000, to remain available until September 30, 2019, of which not to exceed $500,000,000 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, $760,550,000, to remain available until September 30, 2019.

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, $182,800,000, 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; $328,510,000: *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 2018 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 $5,000,000 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, $15,008,000, of which $400,000 shall remain available until September 30, 2019.

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.), $4,370,000: *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 10 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 2018 NSF BUDGETARY RESOURCES BY ACCOUNT

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request	Change Over FY 2017 Annualized CR Amount	Percent
RESEARCH AND RELATED ACTIVITIES					
Appropriation	$6,033.65	$6,022.18	$5,361.65	-$660.53	-11.0%
Unobligated Balance Available Start of Year	10.08	11.93		-11.93	
Unobligated Balance Available End of Year	-11.93				
Adjustments to Prior Year Accounts[1]	10.26				
Subtotal, R&RA	6,042.06	6,034.11	5,361.65	-672.46	-11.1%
Transfer to AOAM	-23.97				
Transfer to MREFC	-20.00				
Total Budgetary Resources	$5,998.09	$6,034.11	$5,361.65	-$672.46	-11.1%
EDUCATION AND HUMAN RESOURCES					
Appropriation	$880.00	$878.33	$760.55	-$117.78	-13.4%
Unobligated Balance Available Start of Year	2.63	5.37		-5.37	
Unobligated Balance Available End of Year	-5.37				
Adjustments to Prior Year Accounts[1]	7.87				
Subtotal, EHR	885.13	883.70	760.55	-123.15	-13.9%
Transfer to AOAM	-1.03				
Total Budgetary Resources	$884.10	$883.70	$760.55	-$123.15	-13.9%
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION					
Appropriation	$200.31	$199.93	$182.80	-$17.13	-8.6%
Unobligated Balance Available Start of Year	58.06	37.21		-37.21	
Unobligated Balance Available End of Year	-37.21				
Adjustments to Prior Year Accounts[1]	2.34				
Subtotal, MREFC	223.50	237.14	182.80	-54.34	-22.9%
Transfer to AOAM	-2.00				
Transfer from R&RA	20.00				
Total Budgetary Resources	$241.50	$237.14	$182.80	-$54.34	-22.9%
AGENCY OPERATIONS AND AWARD MANAGEMENT					
Appropriation	$330.00	$329.37	$328.51	-$0.86	-0.3%
Unobligated Balance Available Start of Year	18.11	23.71		-23.71	
Unobligated Balance Available End of Year	-23.71				
Adjustments to Prior Year Accounts[1]	-0.29				
Subtotal, AOAM	324.11	353.08	328.51	-24.57	-7.0%
Transfer from R&RA	23.97				
Transfer from EHR	1.03				
Transfer from MREFC	2.00				
Total Budgetary Resources	$351.11	$353.08	$328.51	-$24.57	-7.0%
NATIONAL SCIENCE BOARD					
Appropriation	$4.37	$4.36	$4.37	$0.01	0.2%
Unobligated Balance - Expired	-0.06				
Total Budgetary Resources	$4.31	$4.36	$4.37	$0.01	0.2%
OFFICE OF INSPECTOR GENERAL					
Appropriation	$15.16	$15.13	$15.01	-$0.12	-0.8%
Unobligated Balance Available Start of Year	0.17	0.38		-0.38	
Unobligated Balance Available End of Year	-0.38				
Adjustments to Prior Year Accounts[1]	-0.19				
Total Budgetary Resources	$14.76	$15.51	$15.01	-$0.50	-3.2%
TOTAL DISCRETIONARY, NATIONAL SCIENCE FOUNDATION	$7,493.87	$7,527.90	$6,652.89	-$875.01	-11.6%

[1]Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

SUMMARY OF FY 2018 BUDGETARY RESOURCES BY ACCOUNT

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized Estimate	FY 2018 Request	Change Over FY 2016 Actual Amount	Change Over FY 2016 Actual Percent
EDUCATION AND HUMAN RESOURCES, H-1B					
Appropriation, Mandatory (H1-B Non-Immigrant Petitioner Fees)	$138.79	$100.00	$100.00	-	-
Unobligated Balance Available Start of Year	116.02	74.63		-74.63	
Sequestration Previously Unavailable	7.30	6.80		-6.80	
Sequestration Pursuant OMB M-13-06	-6.80				
Unobligated Balance Available End of Year	-74.63				
Adjustments to Prior Year Accounts[1]	4.20				
Total Budgetary Resources	$184.89	$181.43	$100.00	-$81.43	-44.9%
DONATIONS					
Mandatory Programs (Special or Trust Fund)	$24.44	$35.00	$35.00	-	-
Unobligated Balance Available Start of Year	29.12	23.93		-23.93	
Unobligated Balance Available End of Year	-23.93				
Adjustments to Prior Year Accounts[1]	0.48				
Total Budgetary Resources	$30.11	$58.93	$35.00	-$23.93	-40.6%
TOTAL, NATIONAL SCIENCE FOUNDATION	$7,708.85	$7,768.26	$6,787.89	-$980.37	-12.6%

[1]Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

NSF FY 2018 FUNDING BY PROGRAM

(Dollars in Millions)

PROGRAM	FY 2016 Actual	FY 2017 Annualized CR (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual Amount	Percent
BIOLOGICAL SCIENCES (BIO)					
BIOLOGICAL INFRASTRUCTURE	$144.61	-	$169.61	$25.00	17.3%
EMERGING FRONTIERS	85.53	-	137.31	51.78	60.5%
ENVIRONMENTAL BIOLOGY	143.96	-	130.78	-13.18	-9.2%
INTEGRATIVE ORGANISMAL SYSTEMS	214.21	-	111.20	-103.01	-48.1%
MOLECULAR & CELLULAR BIOSCIENCES	135.46	-	123.21	-12.25	-9.0%
TOTAL, BIO	**$723.78**	**-**	**$672.11**	**-$51.67**	**-7.1%**
COMPUTER & INFORMATION SCIENCE & ENGINEERING (CISE)					
ADVANCED CYBERINFRASTRUCTURE	$222.19	-	$199.31	-$22.88	-10.3%
COMPUTING & COMMUNICATION FOUNDATIONS	194.13	-	174.14	-19.99	-10.3%
COMPUTER & NETWORK SYSTEMS	230.99	-	207.21	-23.78	-10.3%
INFORMATION & INTELLIGENT SYSTEMS	194.80	-	174.75	-20.05	-10.3%
INFORMATION TECHNOLOGY RESEARCH	93.09	-	83.51	-9.58	-10.3%
TOTAL, CISE	**$935.20**	**-**	**$838.92**	**-$96.28**	**-10.3%**
ENGINEERING (ENG)					
CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, & TRANSPORT SYSTEMS	$183.76	-	$168.20	-$15.56	-8.5%
CIVIL, MECHANICAL, & MANUFACTURING INNOVATION	216.27	-	202.20	-14.07	-6.5%
ELECTRICAL, COMMUNICATIONS, & CYBER SYSTEMS	113.89	-	102.85	-11.04	-9.7%
INDUSTRIAL INNOVATION & PARTNERSHIPS	239.87	-	223.21	-16.66	-6.9%
[SBIR/STTR]	*188.56*	-	*176.21*	*-12.35*	*-6.5%*
ENGINEERING EDUCATION & CENTERS	107.51	-	100.28	-7.23	-6.7%
EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES	54.37	-	36.75	-17.62	-32.4%
TOTAL, ENG	**$915.68**	**-**	**$833.49**	**-$82.19**	**-9.0%**
GEOSCIENCES (GEO)					
ATMOSPHERIC & GEOSPACE SCIENCES	$253.54	-	$227.68	-$25.86	-10.2%
EARTH SCIENCES	179.67	-	161.01	-18.66	-10.4%
INTEGRATIVE & COLLABORATIVE EDUCATION AND RESEARCH	83.47	-	71.60	-11.87	-14.2%
OCEAN SCIENCES	359.83	-	323.02	-36.81	-10.2%
TOTAL, GEO	**$876.51**	**-**	**$783.31**	**-$93.20**	**-10.6%**

NSF FY 2018 Funding by Program

(Dollars in Millions)

PROGRAM	FY 2016 Actual	FY 2017 Annualized CR (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual Amount	Percent
MATHEMATICAL & PHYSICAL SCIENCES (MPS)					
ASTRONOMICAL SCIENCES	$246.63	-	$221.15	-$25.48	-10.3%
CHEMISTRY	246.52	-	221.05	-25.47	-10.3%
MATERIALS RESEARCH	309.88	-	282.87	-27.01	-8.7%
MATHEMATICAL SCIENCES	233.95	-	209.78	-24.17	-10.3%
PHYSICS	276.91	-	253.30	-23.61	-8.5%
MULTIDISCIPLINARY ACTIVITIES	34.89	-	31.28	-3.61	-10.3%
TOTAL, MPS	**$1,348.78**	**-**	**$1,219.43**	**-$129.35**	**-9.6%**
SOCIAL, BEHAVIORAL & ECONOMIC SCIENCES (SBE)					
BEHAVIORAL AND COGNITIVE SCIENCES	$95.01	-	$85.32	-$9.69	-10.2%
SOCIAL AND ECONOMIC SCIENCES	98.12	-	87.06	-11.06	-11.3%
MULTIDISCIPLINARY ACTIVITIES	28.32	-	23.45	-4.87	-17.2%
NATIONAL CENTER FOR SCIENCE & ENGINEERING STATISTICS	50.74	-	48.19	-2.55	-5.0%
TOTAL, SBE	**$272.20**	**-**	**$244.02**	**-$28.18**	**-10.4%**
OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE)	**$49.07**	**-**	**$44.02**	**-$5.05**	**-10.3%**
OFFICE OF POLAR PROGRAMS (OPP)					
OFFICE OF POLAR PROGRAMS	448.87	-	409.18	-39.69	-8.8%
[US Antarctic Logistical Support Activities]	*67.52*	-	*71.00*	*3.48*	*5.2%*
TOTAL, OPP	**$448.87**	**-**	**$409.18**	**-$39.69**	**-8.8%**
OFFICE OF INTEGRATIVE ACTIVITIES (OIA)					
EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCOR)	160.03	-	100.00	-60.03	-37.5%
INTEGRATIVE ACTIVITIES	266.53	-	215.74	-50.79	-19.1%
[Major Research Instrumentation (MRI)]	*75.69*	-	*75.00*	*-0.69*	*-0.9%*
TOTAL, OIA	**$426.57**	**-**	**$315.74**	**-$110.83**	**-26.0%**
UNITED STATES ARCTIC RESEARCH COMMISSION	**$1.43**	**-**	**$1.43**	**-**	**-**
TOTAL, RESEARCH AND RELATED ACTIVITIES	**$5,998.09**	**$6,022.18**	**$5,361.65**	**-$636.44**	**-10.6%**
EDUCATION & HUMAN RESOURCES (EHR)					
GRADUATE EDUCATION	$278.19	-	$221.29	-$56.90	-20.5%
HUMAN RESOURCE DEVELOPMENT	149.31	-	135.30	-14.01	-9.4%
RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS	224.32	-	199.57	-24.75	-11.0%
UNDERGRADUATE EDUCATION	232.29	-	204.39	-27.90	-12.0%
TOTAL, EDUCATION & HUMAN RESOURCES	**$884.10**	**$878.33**	**$760.55**	**-$123.55**	**-14.0%**

NSF FY 2018 Funding by Program

(Dollars in Millions)

PROGRAM	FY 2016 Actual	FY 2017 Annualized CR (TBD)	FY 2018 Request	FY 2018 Request Change Over FY 2016 Actual Amount	Percent
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION	**$241.50**	**$199.93**	**$182.80**	**-$58.70**	**-24.3%**
AGENCY OPERATIONS AND AWARD MANAGEMENT	**$351.11**	**$329.37**	**$328.51**	**-$22.60**	**-6.4%**
OFFICE OF THE INSPECTOR GENERAL	**$14.76**	**$15.13**	**$15.01**	**$0.25**	**1.7%**
NATIONAL SCIENCE BOARD	**$4.31**	**$4.36**	**$4.37**	**$0.06**	**1.5%**
TOTAL, NATIONAL SCIENCE FOUNDATION	**$7,493.87**	**$7,449.30**	**$6,652.89**	**-$840.99**	**-11.2%**

NSF BY OBJECT CLASSIFICATION
Consolidated Obligations
(Dollars in Millions)

Object Class Code	Standard Title	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request
11.1	Full-time permanent	$156	-	$167
11.3	Other than full-time permanent	13	-	15
11.5	Other personnel compensation	2	-	3
11.8	Special personal service payment[1]	1	-	50
	Total personnel compensation	172	-	235
12.1	Civilian personnel benefits	53	-	56
21.0	Travel and transportation of persons	23	-	23
22.0	Transportation of things	1	-	1
23.1	Rental payments	33	-	27
23.2	Rental payments to others	-	-	1
23.3	Communications, utilities, and	2	-	3
	miscellaneous charges		-	
25.1	Advisory and assistance services	224	-	194
25.2	Other services	20	-	21
25.3	Purchases of goods and services from	144	-	82
	Government accounts		-	
25.4	Operation and maintenance of facilities	214	-	270
25.5	Research and development contracts	5	-	5
25.7	Operation and maintenance of equipment	-	-	-
26.0	Supplies and materials	1	-	1
31.0	Equipment	7	-	6
41.0	Grants, subsidies, and contributions	6,809	-	5,864
	Total, Direct obligations [2,3]	$7,709	-	$6,789

[1]Reclassification of costs by object class in fiscal year 2018 from 41.0 (Grants) to 11.8 (Special personal service payment) for Intergovernmental Personnel Act agreements. This conforms with OMB Circular A-11, Section 83.

[2]Includes mandatory obligations, but excludes obligations for reimbursable accounts.

[3]Actual and estimated reimbursble obligations for fiscal years 2016 through 2018 total $5 million, $10 million, and $10 million for Agency Operations and Award Management, $84 million, $126 million, and $120 million for Research and Related Activities, and $5 million, $15 million, and $15 million in Education and Human Resources.

NSF 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 2016 Actual
DEFENSE	
Air Force	$8.2
Army	5.8
Other DoD (DARPA, NSA & Intelligence)	11.5
Subtotal, DoD	$25.5
Commerce (Including Census, NOAA, & NIST)	16.8
Energy	10.9
Health & Human Services	19.5
Homeland Security	2.9
Interior	0.6
Justice	1.0
NASA	8.2
State	0.0
Transportation	1.3
EPA	0.7
OTHER (less than $500,000)	1.4
TOTAL REIMBURSEMENTS	**$88.7**

Consistent with applicable legislation and GAO decisions, agreements include reimbursement for costs that are incurred in the management and administration of these awards.

EXPLANATION OF FY 2016 CARRYOVER INTO FY 2017 BY ACCOUNT

The National Science Foundation's (NSF) total unobligated balance of $183.46 million ($84.90 million for Discretionary accounts, including $6.30 million for Incoming Interagency Reimbursable Agreements, and $98.56 million for Mandatory accounts) is described below.

DISCRETIONARY

Within the **Research and Related Activities (R&RA)** account, $18.23 million (including $6.30 million in reimbursable funds) was carried over into FY 2017.

Directorate for Geosciences Polar Programs (no-year funding)

- Amount: $2.06 million
- Reason: Recoveries from prior year obligations that were received too late in the fiscal year to obligate.
- Obligated: FY 2017 Quarter 2

Office of Integrative Activities (OIA)

- Amount: $6.33 million
- Reason: The complexity of co-funding for several INSPIRE awards prevented the timely obligation of these funds.
- Anticipated Obligation: FY 2017 Quarter 3

- Amount: $199,402
- Reason: Processing a new awardee in the Major Research Instrumentation Program delayed obligating the award.
- Anticipated Obligation: FY 2017 Quarter 3

National Coordination Office for Networking and Information Technology Research and Development (NCO/NITRD)

- Amount: $617,984
- Reason: NCO was unable to secure a lease with GSA in time to obligate the funds. The Reimbursable Work Authorization was completed in November 2016.
- Obligated: FY 2017 Quarter 1

National Nanotechnology Coordination Office (NNCO)

- Amount: $215,012
- Reason: NNCO's planned move and the timing of GSA's negotiation of the new lease precluded obligating the funds in FY 2016. In addition, carryover funding was needed to cover costs to complete the required Nuclear Regulatory Commission study.
- Obligated: FY 2017 Quarter 1

The remaining R&RA carryover of $2.50 million consists of funds from throughout the Foundation for projects that were not ready for obligation in FY 2016.

Within the **Education and Human Resources (EHR)** account, $5.37 million was carried over into FY 2017.

Excellence Awards in Science and Engineering (EASE)

- Amount: $2.93 million

- Reason: Delays in the selection of a contractor to assist with the administration of the Presidential Awards for Excellence in Mathematics and Science Teaching program, which is managed by EHR on behalf of OSTP.
- Obligated: FY 2017 Quarter 2

Inclusion Across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES)
- Amount: $720,192
- Reason: Delays in obligation is due to the pre-award process for multiple new awardees.
- Obligated: FY 2017 Quarter 1

Robert Noyce Scholarship Program
- Amount: 1.62 million
- Reason: Robert Noyce program funding was carried over into FY 2017 for awards that were not ready for obligation.
- Anticipated Obligation: FY 2017 Quarter 4

The remaining $97,719 are residual funds from various EHR program activities.

Within the **Major Research Equipment and Facilities Construction** no-year account, $37.21 million was carried over into FY 2017.

National Ecological Observatory Network (NEON)
- Amount: $28.41 million
- Reason: FY 2016 obligations were limited due to construction management transition. For additional information, please see the NEON section of the MREFC Chapter.
- Obligated: FY 2017 Quarter 1

Large Synoptic Survey Telescope (LSST)
- Amount: $6.70 million
- Reason: These funds reflect updated NSF policy for the oversight of contingency, as discussed in the MREFC chapter.
- Anticipated Obligation: TBD - Funds held in reserve until needed.

The remaining $2.10 million is from completed projects. These projects are Ocean Observatories Initiative, Atacama Large Millimeter Array, South Pole Station Modernization, Advanced Laser Interferometer Gravitational Wave Observatory, and Large Hadron Collider. A portion of these carryover funds will be used for the enhanced oversight of MREFC projects.

Within the **Agency Operations and Award Management** (AOAM) no-year component, $23.71 million was carried over into FY 2017.

NSF Headquarters Relocation
- Amount: $23.71 million
- Reason: Obligations planned for FY 2016 were shifted to FY 2017.
- Anticipated Obligation: FY 2017 Quarter 3

Within the **Office of Inspector General (OIG)** two-year account, $380,002 was carried over into FY 2017.

Office of the Inspector General

- Amount: $380,002
- 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 2017 Quarter 4

MANDATORY

Within the **H-1B** no-year account, $74.63 million was carried over into FY 2017.

Innovation Technology Experiences for Students (ITEST)

- Amount: $18.66 million
- Reason: 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 2017 Quarter 4

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)

- Amount: $55.97 million
- Reason: 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 2017 Quarter 4

Within the **Donations** account, $23.93 million was carried over into FY 2017. Donations were received from foreign governments, organizations, and individuals to fund various cooperative efforts in science, research, and education.

Distribution of FY 2016 Carryover into FY 2017
Discretionary and Mandatory Accounts
(Dollars in Millions)

Discretionary Accounts	Amount
Research and Related Activities	$18.23
Education and Human Resources	5.37
Major Research Equipment and Facilities Construction	37.21
Agency Operations and Award Management	23.71
Office of Inspector General	0.38
Subtotal	**84.90**
Mandatory Accounts	
H-1B Non-Immigrant Petitioner	74.63
Donations (Special or Trust Fund)	23.93
Subtotal	**98.56**
TOTAL	**$183.46**

EXPLANATION OF VARIANCE OF FY 2016 ACTUALS AND FY 2016 ENACTED

(Dollars in Millions)

	FY 2016 Enacted Level	FY 2016 Actuals	FY 2016 Actuals change over FY 2016 Enacted		Explanation of Variance: FY 2016 Actuals vs. FY 2016 Enacted			
			Amount	Percent	Appropriation Transfer (Net)	Obligations From Prior Year Appropriations	Recoveries and Other Adjustments	Unobligated Funds Carried Over to FY 2017
Research and Related Activities	$6,033.65	$5,998.09	-$35.56	-0.6%	-$43.97	$10.79	$9.55	-$11.93
Education and Human Resources	880.00	884.10	4.10	0.5%	-1.03	2.20	8.30	-5.37
Major Research Equipment and Facilities Construction	200.31	241.50	41.19	20.6%	18.00	56.00	4.40	-37.21
Award Management and Agency Operations	330.00	351.11	21.11	6.4%	27.00	17.82	-	-23.71
Office of Inspector General	15.16	14.76	-0.40	-2.6%	-	-	-0.02	-0.38
National Science Board	4.37	4.31	-0.06	-1.4%	-	-	-0.06	-
Total, National Science Foundation	**$7,463.49**	**$7,493.86**	**$30.38**	**0.4%**	**-**	**$86.81**	**$22.17**	**-$78.60**

Total excludes reimbursable obligations

In the FY 2018 NSF Budget Request, the amounts shown in the column labeled FY 2016 Actuals represent the actual obligations that occurred in FY 2016. These amounts include the obligation of prior year appropriations and other adjustments, and are therefore different from the FY 2016 Enacted Level. The sources of the variation are:

- Transfer of funds across appropriation accounts.
- Recoveries from prior year appropriations. This occurs when an award obligated in FY 2015 was de-obligated in FY 2016 and then re-obligated in FY 2016.
- Unobligated funds carried over from the previous year.

Most activities in the R&RA and EHR accounts have two-year funding, so the carry over and the recoveries are associated with the FY 2015 appropriation. Funding for Polar Programs, Robert Noyce Teacher Scholarship Program and Major Research Equipment and Facilities Construction activities is no-year, so additional obligations in FY 2016 could be associated with earlier years as well.

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE FOUNDATION

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
Investment Activities			
Conduct of Research and Development			
Basic Research	$4,829.30	-	$4,279.50
Applied Research	760.13	-	670.79
Subtotal, Conduct of R&D	5,589.43	-	4,950.29
Physical Assets			
Research and Development Facilities	254.91	-	194.81
Research and Development Major Equipment	177.94	-	224.84
Subtotal, R&D Facilities & Major Equipment	432.85	-	419.65
Total, Research and Development	6,022.28	-	5,369.94
Conduct of Education and Training	760.85	-	635.52
Non-Investment Activities	710.74	-	647.43
TOTAL	$7,493.87	$7,449.30	$6,652.89

QUANTITATIVE DATA TABLE

RESEARCH AND RELATED ACTIVITIES

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
Investment Activities			
Conduct of Research and Development			
Basic Research	$4,689.29	-	$4,159.50
Applied Research	495.31	-	442.79
Subtotal, Conduct of R&D	5,184.60	-	4,602.29
Physical Assets			
Research and Development Facilities	13.43	-	12.01
Research and Development Major Equipment	177.72	-	224.65
Subtotal, R&D Facilities & Major Equipment	191.15	-	236.66
Total, Research and Development	5,375.75	-	4,838.95
Conduct of Education and Training	320.24	-	256.52
Non-Investment Activities	302.10	-	266.18
TOTAL	$5,998.09	$6,022.18	$5,361.65

QUANTITATIVE DATA TABLE

EDUCATION AND HUMAN RESOURCES

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
Investment Activities			
Conduct of Research and Development			
Basic Research	$140.01	-	$120.00
Applied Research	264.82	-	228.00
Subtotal, Conduct of R&D	404.83	-	348.00
Physical Assets			
Research and Development Facilities	-	-	-
Research and Development Major Equipment	0.22	-	0.19
Subtotal, R&D Facilities & Major Equipment	0.22	-	0.19
Total, Research and Development	405.05	-	348.19
Conduct of Education and Training	440.61	-	379.00
Non-Investment Activities	38.44	-	33.36
TOTAL	$884.10	$878.33	$760.55

QUANTITATIVE DATA TABLE

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
Investment Activities			
Conduct of Research and Development			
Basic Research	-	-	-
Applied Research	-	-	-
Subtotal, Conduct of R&D	-	-	-
Physical Assets			
Research and Development Facilities	$241.48	-	$182.80
Research and Development Major Equipment	-	-	-
Subtotal, R&D Facilities & Major Equipment	241.48	-	182.80
Total, Research and Development	241.48	-	182.80
Conduct of Education and Training	-	-	-
Non-Investment Activities	0.02	-	-
TOTAL	$241.50	$199.93	$182.80

QUANTITATIVE DATA TABLE

AGENCY OPERATIONS AND AWARD MANAGEMENT

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
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	$351.11	-	$328.51
TOTAL	$351.11	$329.37	$328.51

QUANTITATIVE DATA TABLE

OFFICE OF INSPECTOR GENERAL

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Annualized CR	FY 2018 Request
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	$14.76	-	$15.01
TOTAL	$14.76	$15.13	$15.01

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE BOARD

Research and Development Special Analysis

(Dollars in Millions)

	FY 2016 Actual	**FY 2017 Annualized CR**	**FY 2018 Request**
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	$4.31	-	$4.37
TOTAL	$4.31	$4.36	$4.37