NATIONAL SCIENCE FOUNDATION

FY 2020 Budget Request to Congress

March 18, 2019

NOTES

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

Amounts for FY 2019 were not available at the time this Budget Request was published.

Common Acronyms Used in Budget Request to Congress

<u>Appropriation Accounts</u>
- AOAM - Agency Operations and Award Management
- EHR - Education and Human Resources
- MREFC - Major Research Equipment and Facilities Construction
- NSB - National Science Board
- OIG - Office of Inspector General
- R&RA - Research and Related Activities

<u>Directorates and offices</u>
- BFA - Office of Budget, Finance, and Award Management
- BIO - Directorate for Biological Sciences
- CISE - Directorate for Computer and Information Science and Engineering
- ENG - Directorate for Engineering
- EHR - Directorate for Education and Human Resources
- GEO - Directorate for Geosciences
- MPS - Directorate for Mathematical and Physical Sciences
- SBE - Directorate for Social, Behavioral, and Economic Sciences
- OIRM - Office of Information and Resource Management
- OISE - Office of International Science and Engineering
- OPP - Office of Polar Programs
- OIA - Office of Integrative Activities [organizational unit]
- IA - Integrative Activities [budget activity]

<u>NSF Big Ideas</u>
Convergence Accelerator
- NSF C-Accel - NSF Convergence Accelerator

Research Big Ideas
- HDR - Harnessing the Data Revolution for 21^{st}-Century Science and Engineering
- FW-HTF - The Future of Work at the Human-Technology Frontier
- NNA - Navigating the New Arctic
- QL - The Quantum Leap: Leading the Next Quantum Revolution
- URoL - Understanding the Rules of Life: Predicting Phenotype
- WoU - Windows on the Universe: The Era of Multi-messenger Astrophysics

Enabling Big Ideas
- GCR - Growing Convergence Research at NSF
- Mid-scale RI - Mid-scale Research Infrastructure
- NSF INCLUDES - Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science
- NSF 2026 - NSF 2026: Seeding Innovation

Notes

NSF-Wide Investments

- GRFP - Graduate Research Fellowship Program
- INFEWS - Innovations at the Nexus of Food, Energy, and Water Systems
- IUSE - Improving Undergraduate STEM Education
- I-Corps™ - NSF Innovation Corps
- NRT - NSF Research Traineeship
- SaTC - Secure and Trustworthy Cyberspace
- UtB - Understanding the Brain
    - BRAIN Initiative - Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative

National Science and Technology Council Crosscuts:

- NITRD - Networking and Information Technology Research and Development
- NNI - National Nanotechnology Initiative
- USGCRP - U.S. Global Change Research Program

Other Frequently Used Acronyms

- STEM - Science, Technology, Engineering, and Mathematics
- R&D - Research and Development

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

On September 22, 2017, after travelling billions of light years through space, a neutrino finally made its way to IceCube, a large neutrino observatory located under the ice at the South Pole. There the neutrino collided with an atom in the ice, producing a shower of particles that were detected by IceCube's sensors. This became the first detection of a high-energy neutrino that can be traced back to an identified source—a type of galaxy known as a blazar, with a central massive black hole that powers high-velocity jets of particles. Neutrinos are nearly massless particles that can pass through anything they encounter, whether people, planets or galaxies. They are therefore difficult to detect. However, if one of these cosmic messengers is "stopped in its tracks" here on Earth, high-technology instrumentation can, at least in principle, pinpoint the location of its origin. In 2004 scientists began developing the means to do just that, namely, to use the vast quantities of clear ice at the South Pole as a way to stop, or capture, neutrinos and to thus try to infer important information about their origin.

An NSF commitment to this project fourteen years ago allowed scientists and engineers to begin melting holes 2.4 kilometers (1.5 miles) deep in the ice of the South Pole and dropping in more than 80 strings of light sensors, which number 5,160 in all. Today, this cubic kilometer of instrumented ice, containing enough water to fill one million swimming pools, is home to what promises to be some of the most exciting science of our time. The recent neutrino detection, coupled with past detections of neutrinos by IceCube, has already generated new knowledge. Emissions from the jets of blazars contain not only neutrinos but vast quantities of other subatomic particles and high-energy radiation. Correlation of the neutrino detection with space and ground-based observations of gamma-radiation emitted by these jets confirms the blazar as the first identified source of high-energy cosmic rays, thus solving the 100-year-old mystery of their origin.

A long-term vision, belief in the promise of fundamental research, and commitment to risky, but potentially extraordinary discoveries are the hallmarks of NSF. NSF's investments empower discoverers to ask the questions and develop the technologies that lead to the next big breakthroughs.

In FY 2020, NSF will continue to support the science, technology, innovation and workforce development that drives this Nation's economy, ensures the security of the American people, and secures the U.S.'s place as a global power for generations to come. To achieve these goals, NSF will make strategic investments across the agency to support the heart of NSF's mission, basic research, while putting an emphasis on convergence—interdisciplinary research that spans and integrates all areas of science. FY 2020 investments support the Administration's Research and Development Budget Priorities, including artificial intelligence (AI); quantum information science (QIS) research; advanced manufacturing; and microelectronics and semiconductors. These investments will strengthen the Nation's innovation base and contribute to unparalleled job growth, continued prosperity, and national security.

NSF funds the basic research that builds the foundation of human knowledge while making possible innovations in life-saving medical diagnostics, machine learning, precision agriculture, and countless other areas. Investments in basic and early-stage research create the foundation for these breakthroughs. NSF invests in basic research across all areas of non-medical science and engineering and integrates these investments with dedicated efforts to educate and train a diverse workforce for the 21st century economy. Since the agency's founding in 1950, NSF has been at the forefront of the innovations that enhance American prosperity and strength, while ensuring that the Nation's technological and scientific advancements remain the envy of the world. If the U.S. is to remain the global leader in innovation, NSF's role is ever more important.

NSF continues to emphasize its 10 Big Ideas, research agendas that identify areas at the frontiers of science and engineering which promise to be among the most transformative in the coming decade. FY 2020 investments will build on progress made in prior years to seed or establish these Big Ideas. Of the 10 Big Ideas, six are Research Ideas. These are opportunities for researchers to make the discoveries that will shape the future of everything from quantum computing, artificial intelligence, and agriculture to space exploration and medical innovation. Each of these ideas will be supported by dedicated investments in core Big Ideas activities, as well as additional investment in foundational support from across the agency. The other four are Enabling Big Ideas, which endeavor to make science and engineering more interdisciplinary and reflective of the rich diversity of the U.S., while supporting investments in infrastructure and risky, high-reward science. For more on NSF's Big Ideas, see the next section of the Overview and the NSF-Wide Investments chapter.

NSF promotes efficient and effective management and support of R&D infrastructure of all scopes and in all disciplines. In response to the 2017 American Innovation and Competitiveness Act, NSF named a Chief Officer for Research Facilities (CORF) in the Office of the Director, responsible for full life-cycle oversight of NSF's major multi-user research facilities. At the request of Congress, the National Science Board (NSB) produced a comprehensive assessment of the Operations and Maintenance (O&M) funding and management of such facilities, and the impact of O&M funding on the science enterprise. The first recommendation of the NSB report was that "NSB and the NSF Director should continue to enhance agency-level ownership of the facility portfolio through processes that elevate strategic and budgetary decision-making." NSF responded to this recommendation during FY 2018 by directing a significant portion of the appropriations above the FY 2018 Request toward deferred maintenance and upgrades at major facilities. In FY 2019 and FY 2020, NSF will continue to prioritize the health and balance of its facilities portfolio. Specifically, the agency will initiate a pilot project that reflects NSF's strategic commitment to successful O&M. The funds in this activity will be used to (1) partially support initial O&M of new facilities so that the full O&M costs can be gradually absorbed into the managing division or directorate, and (2) partially support divestment of lower-priority facilities, the full cost of which may significantly impact individual division or directorate funding. The tables presented in the Budget Request reflect these priorities for FY 2020. NSF will continue to examine options to provide long-term stability to O&M and the annual investment of over $1 billion in major facilities at all life-cycle stages.

NSF will continue support for the Antarctic Infrastructure Modernization for Science (AIMS) project. Antarctic facilities are a critical part of the American R&D infrastructure and must be modernized to ensure that the Nation has the most up-to-date capabilities. These are vital to guarantee that the U.S. continues to have unimpeded access to Antarctica and to ensure that the discoveries made on the continent can continue for decades to come. In FY 2020, this project will be funded in the MREFC account.

Investments in education and STEM workforce are vital to the Nation's continued global leadership. NSF is a leader in federal efforts to: educate and train a workforce for the 21st century economy; remove barriers to participation in STEM careers; increase diversity, equity, and inclusion in STEM; and promote excellence in STEM education for all learners. Collectively, NSF's Education and STEM workforce programs educate, train, and support discoverers, engage citizen scientists, and foster a well-informed, STEM-literate citizenry prepared to handle rapid technological change and pursue STEM careers.

NSF continues to prioritize a strong relationship with the private sector. Through innovative operational constructs like the Convergence Accelerator, and programs like Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and I-Corps™, NSF will continue to support the basic and early-stage applied research that provides the fundamental building blocks of technological advances. Each Convergence Accelerator track is prepared to leverage $20.0 million per year in public-private partnerships. SBIR, STTR, and I-Corps™ will also continue to empower the private sector to accelerate the transfer of research discoveries. By working to ensure a robust private-public partnership, NSF aims to prioritize lab-to-market initiatives and technology transfer, and to develop an entrepreneurial workforce of STEM professionals.

NSF's FY 2020 Budget Request is $7.066 billion, a 9.6 percent decrease from the FY 2018 Actual level and a 12.6 percent decrease from the FY 2019 Enacted level

NSF's 10 Big Ideas and the Convergence Accelerator

In 2020, NSF will continue to invest in its 10 Big Ideas and the Convergence Accelerator, which support bold inquiries into the frontiers of science and engineering. These efforts endeavor to break down the silos of conventional scientific research funded by NSF to embrace the cross-disciplinary and dynamic nature of the science of the future. The Big Ideas represent unique opportunities for the U.S. to define and push the frontiers of global science and engineering leadership and to invest in fundamental research. This research will advance the Nation's economic competitiveness, security, and prestige on the global stage. For more information, see the NSF-Wide Investments chapter.

About the Big Ideas

Six of the Big Ideas are research ideas, which will build on the foundation of NSF-funded research over the last 69 years. The Research Big Ideas are complemented by four Enabling Big Ideas, which are areas in which research endeavors to improve the way in which science is done, from impacting the workforce to developing the infrastructure that will drive the discoveries and aid the discoverers of tomorrow's science.

Research Big Ideas:

1. **Harnessing the Data Revolution for 21st-Century Science and Engineering (HDR)**—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.

2. **The Future of Work at the Human Technology Frontier (FW-HTF)**—Catalyzing interdisciplinary science and engineering research to understand and build the human-technology relationship; design new technologies to augment human performance; illuminate the emerging socio-technological landscape; and foster lifelong and pervasive learning with technology.

3. **Windows on the Universe (WoU): 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 to answer some of the most profound questions before humankind.

4. **The Quantum Leap (QL): Leading the Next Quantum Revolution**—Exploiting quantum mechanics to observe, manipulate, and control the behavior of particles and energy at atomic and subatomic scales; and developing next-generation quantum-enabled science and technology for sensing, information processing, communicating, and computing.

5. **Understanding the Rules of Life (URoL): Predicting Phenotype**—Elucidating the sets of rules that predict an organism's observable characteristics.

6. **Navigating the New Arctic (NNA)**—Establishing an observing network of mobile and fixed platforms and tools, including cyber tools, across the Arctic to document and understand the Arctic's rapid biological, physical, chemical, and social changes, in partnership with other agencies, countries, and native populations.

Enabling Big Ideas:

7. **NSF INCLUDES—**Transforming education and career pathways to help broaden participation in science and engineering.

8. **Growing Convergence Research at NSF (GCR)—**Merging ideas, approaches, tools, and technologies from widely diverse fields of science and engineering to stimulate discovery and innovation.

9. **Mid-scale Research Infrastructure—**Developing an agile process for funding experimental research capabilities in the mid-scale range, spanning the midscale gap in research infrastructure. This is a "sweet spot" for science and engineering that has been challenging to fund through traditional NSF programs.

10. **NSF 2026 Fund—**Stimulating and seeding investments in bold foundational research questions that are large in scope, innovative in character, originate outside of any particular NSF directorate, and may require long-term support. This Big Idea is framed around the year 2026, providing an opportunity for transformative research to mark the Nation's 250th anniversary.

About the Convergence Accelerator

In the FY 2019 Budget Request to Congress, NSF unveiled the Convergence Accelerator, a new organizational framework that stands separately from the NSF research directorates, with its own budget, staff, and initiatives. Each accelerator track will be a time-limited entity focused on specific research topics and themes. The Accelerator will reward high-risk, innovative thinking by multidisciplinary teams of researchers who want to accelerate discovery and innovation. The Convergence Accelerator can be a new way of achieving rapid lab-to-market or research outcomes.

Big Ideas and Convergence Accelerator Stewardship Funding Model

The fundamental research underlying the Big Ideas has been supported through many NSF programs for a number of years, and in some cases, for decades. The Big Ideas offer a new strategic framework for messaging important grand challenges. FY 2020 Budget Request to Congress will accelerate NSF's progress on the Big Ideas through the following funding models:

Research Big Ideas: Each of the Big Ideas will have a steward, which will be the directorate that oversees budget management and reporting. An investment of $30.0 million is requested for each of the six research Big Ideas. This stewardship funding will support activities across the agency contributing to support each Big Idea. A total of $180.0 million will be invested across the agency to support the development of the foundational science and technology that will be necessary to propel the Big Ideas forward. These "stewardship investments" are in addition to the significant, foundational investments already being made by individual NSF directorates and offices in these areas. These additional investments for each of the Big Ideas will support convergent research that transcends traditional disciplinary boundaries of individual NSF directorates and offices. The research directions for a Big Idea will be overseen and managed collaboratively by the steward of the corresponding Big Idea and leadership from other participating directorates and offices.

Enabling Big Ideas: The budgets of each these ideas are included in the Integrative Activities, the Directorate for Education and Human Resources or the Major Research Equipment and Facilities Construction account, depending on where the expertise and internal infrastructure exists to ensure success of these endeavors. As with the research ideas, design, direction and implementation are directed by cross-agency working groups. This investment totals $117.50 million and includes NSF INCLUDES, Growing Convergence Research at NSF, Mid-scale Research Infrastructure, and the NSF 2026 Fund.

Convergence Accelerator: In FY 2020, they will focus on topics shared by two of the 10 Big Ideas. One Accelerator track will focus on Harnessing the Data Revolution for 21st-Century Science and Engineering, and a second will focus on the Future of Work at the Human-Technology Frontier. Each will be funded at $30.0 million, plus each will seek to leverage $20.0 million in external partnerships.

Major Research Equipment and Facilities Construction

The FY 2020 Request includes funding to continue construction on two projects: the Large Synoptic Survey Telescope (LSST) and the Antarctic Infrastructure Modernization for Science (AIMS). Funding will begin for two detector upgrades to operate at the High Luminosity-Large Hadron Collider (HL-LHC). Funding for the higher-cost projects ($20 million to $70 million) track of Mid-scale Research Infrastructure will be initiated in MREFC beginning in FY 2020; the track for lower-cost projects ($6 million to $20 million) was initiated in FY 2019 in the R&RA account. The total request to continue construction of these projects, as well as to fund dedicated construction oversight ($1.0 million), is $223.23 million.

MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2018 Actual	FY 2019 Enacted	FY 2020 Request
AIMS	-	103.70	$97.89
DKIST	18.24	16.13	-
HL-LHC Upgrade	-	-	33.00
LSST	66.70	48.82	46.34
Mid-scale Research Infrastructure	-	-	45.00
NEON	12.79	-	-
RCRV	88.00	127.09	-
Dedicated Construction Oversight	0.56	*[1.00]*	1.00
Total	**$186.30**	**$295.74**	**$223.23**

The **AIMS** ($97.89 million) construction project will be supported in MREFC. Antarctica makes up nearly nine percent of the continental mass of Earth's surface. NSF manages all U.S. activities as a single, integrated program, making Antarctic research possible for scientists supported by NSF and other U.S. agencies. Funding this infrastructure improvement project will protect U.S. interests on the continent. AIMS will initiate modernization of major facilities at the aging McMurdo Station, much of which was recommended by the U.S. Antarctic Program Blue Ribbon Panel in 2012, so that anticipated science support needs are met for the next three to five decades. AIMS will enable faster, more streamlined logistical and science support by co-locating or consolidating warehousing, skilled trades work, and field science support where field projects are prepared for movement into the field, into four buildings. AIMS will also provide necessary utilities to support these facilities.

The **LHC** ($33.0 million) is the world's largest and highest energy particle accelerator. Located near Geneva, Switzerland and operated by the European Organization for Nuclear Research (CERN), the LHC can accelerate and collide counter-propagating bunches of protons at a total energy of 14 tera-electron volts. A Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) are two general purpose detectors used by researchers to observe these collisions and analyze their characteristics. In FY 2020, this investment will begin upgrades of components of the ATLAS and CMS detectors that will enable them to function at much higher collision rates following an upgrade to the LHC to increase its luminosity [High Luminosity-Large Hadron Collider (HL-LHC)]. FY 2020 funding would represent year one of a five-year project.

The **LSST** ($46.34 million) will be an 8-meter-class wide-field optical telescope capable of carrying out surveys of the entire southern sky. It will collect nearly 40 terabytes of multi-color imaging data every night to produce the deepest, widest-field sky image ever. It will also issue alerts for moving and transient objects within 60 seconds of their discovery. FY 2020 will be year seven of its nine-year construction funding profile.

The **Mid-scale Research Infrastructure** ($45.0 million) project has a new, dedicated funding line in the MREFC account. In FY 2020, NSF will implement a high-priority, agency-wide mechanism that includes upgrades to major facilities as well as stand-alone projects, such that research infrastructure investments above $20 million are managed as a portfolio. Individual projects will be selected through a dedicated program solicitation developed in FY 2019 and NSF's merit review process.

The FY 2020 Request includes no funding for construction of NSF's **Daniel K. Inouye Solar Telescope (DKIST),** as FY 2019 represented the final year of funding within an 11-year funding profile. Completion of construction is planned for no later than June 2020. The narrative included in the MREFC chapter provides an update on the project's status.

The FY 2020 Request includes no funding for construction of NSF's **RCRV** project, as FY 2019 P.L. 116-6 appropriated $127.09 million, $98.39 million above the FY 2019 requested amount, which is sufficient funding to complete construction of three vessels. The RCRV project will help to satisfy the anticipated ocean science requirements for the Nation through the construction of three new research vessels. The vessels are a major component in the plan for modernizing the U.S. Academic Research Fleet. Construction of three ships to support the anticipated demands for coastal oceanography in the Gulf of Mexico and the East and West coasts will minimize transits and maximize research time in each of these regions. NSF plans to fund the operations of three RCRVs without increasing current annual costs, which is a result of fleet right-sizing and modernization.

Research and Development Budget Priorities

In FY 2020, NSF will make investments that support the basic research that advances human knowledge and make tomorrow's innovations possible. Additional investments will support the advancement of AI, research in advanced manufacturing, and advance discoveries in QIS and semiconductors and microelectronics research. In FY 2020, NSF expects that 93 percent of the annual budget will be used to fund research and education grants and research infrastructure in the science and education communities.

Basic research forms the core of NSF's work and has led to discoveries and innovations that have been awarded Nobel Prizes, and changed humankind's conception of the universe and known world. In FY 2020, NSF expects to invest $4.53 billion, or 64 percent of NSF's total budget, in basic research. Basic research is responsible for advancing our knowledge of the universe, as well as innovations like high speed internet, nanotechnology, and advances in robotics that require understanding of the fundamental laws that govern the physical world. NSF funds basic research in all of the agency's directorates and continues to fund research that transcends a single discipline.

Artificial intelligence (AI) ($492 million) is advancing rapidly and holds the potential to transform American lives through improved educational opportunities, increased economic prosperity, and enhanced national and homeland security. NSF investments in AI span fundamental research in machine learning, computer vision, and natural language processing, along with the safety, security, robustness, and explainability of AI systems; translational research at the intersection of AI and various science and engineering domains as well as economic sectors such as agriculture, manufacturing, and personalized medicine; and education and learning, including growing human capital and institutional capacity to nurture a next generation of AI researchers and practitioners.

Advanced Manufacturing ($268 million) investments support the fundamental research needed to revitalize American manufacturing to grow the national prosperity and workforce, and to reshape our strategic industries. NSF research accelerates advances in manufacturing technologies with emphasis on multidisciplinary research that fundamentally alters and transforms manufacturing capabilities, methods and practices. Investments in advanced manufacturing include research on highly connected cyber-physical systems in smart processing and cyber manufacturing systems, and activities that develop new methods, processes, analyses, tools, or equipment for new or existing manufacturing products, supply chain components, or materials. NSF's investments will enable new functionalities that will increase the efficiency and sustainability of the production of the next generation of products and services. These developments will yield advantages such as reduced time to market, new performance attributes, improved small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

Research in **Quantum Information Science (QIS)** ($106 million) examines uniquely quantum phenomena that can be harnessed to advance information processing, transmission, measurement, and fundamental understanding in ways that classical approaches can only do much less efficiently, or not at all. NSF will increase support for QIS research and development, which strongly aligns with the Administration's National Strategic Overview for QIS and the National Quantum Initiative to consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts.

Research in **semiconductors and microelectronics** ($68 million) is critical to future advances and security in several areas, including information technology, communications, sensing, smart electric grid, transportation, health, and advanced manufacturing. NSF will support research to address fundamental science and engineering questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies. The investment will strengthen America's capabilities and capacity for revolutionary microelectronics design, architecture, and fabrication, as well as high-performance computing. New discoveries will enable the nation to overcome crucial scientific barriers for emerging technologies such as artificial intelligence, quantum technologies, and interconnected autonomous systems, and they will strengthen U.S. scientific leadership, economic prosperity, and national security.

Education and STEM Workforce

NSF's education and STEM workforce investments are primarily housed in the Directorate for Education and Human Resources but represent agency-wide investments in the education of tomorrow's scientists, engineers, and educators. NSF is committed to the education and training of a workforce for the 21st century economy. This workforce must be capable of adapting to the increasingly technical nature of work across all sectors. NSF works to prioritize programs that will provide experiential learning opportunities, as well as programs that prioritize computer science education and reskilling. Priority STEM education activities to prepare America's future workforce in FY 2020 are:

The **Graduate Research Fellowship Program (GRFP)** ($256.9 million) recognizes students with high potential in STEM research and innovation and provides support for them to pursue research across all science and engineering disciplines. GRFP 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. The GRFP program will continue to align awards with NSF research priorities such as Big Data, AI, QIS, and NSF's 10 Big Ideas. In FY 2020, NSF will support 1,600 new fellows.

The **Improving Undergraduate STEM Education (IUSE)** ($93.13 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. The initiative funds the development and implementation and the related research and assessment of effectiveness. Directorates across NSF invest in this program to support the development of a workforce that will be able to handle the real-world challenges of a STEM career.

The **Advanced Technological Education (ATE)** ($75.0 million) program focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary institution school levels. The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways; and other activities.

The **CyberCorps®: Scholarship for Service (SFS)** ($55.09 million) program supports cybersecurity education 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.

The **Robert Noyce Teacher Scholarship** ($47.0 million) program seeks to encourage talented STEM majors and professionals to become K-12 mathematics and science teachers through funding provided to institutions of higher education towards scholarships, stipends, and programmatic support.

The **Louis Stokes Alliance for Minority Participation (LSAMP)** ($46.0 million) program assists universities and colleges in diversifying the nation's STEM workforce by increasing the number of STEM baccalaureate and graduate degrees awarded to populations historically underrepresented in these disciplines.

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, to prepare the STEM workforce of the future. 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 computational thinking into their teaching.

The NSF **ADVANCE** ($18.0 million) program increases representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. ADVANCE is an integral part of the NSF's multifaceted strategy to broaden participation in the STEM workforce and supports the critical role of the Foundation in advancing the status of women in academic science and engineering.

The **Historically Black Colleges and Universities Excellence in Research (HBCU-EiR)** ($10.0 million) program supports projects that enable STEM and STEM education faculty to further develop research capacity at HBCUs and to conduct research.

Performance in Support of Renewing NSF and the Big Ideas

Renewing NSF

With an eye to improving government processes, the Office of Management and Budget issued memorandum M-17-22 in April 2017 requesting that agencies identify opportunities for reform. NSF developed a plan called Renewing NSF. An agency-wide process identified four areas, or "pillars," of greatest opportunity:

- **Making information technology (IT) work for us**
- **Adapting the workforce and the work**
- **Streamlining, standardizing, and simplifying processes and practices**
- **Expanding and deepening public and private partnerships**

NSF's Strategic Reviews in FY 2018 focused on developing the vision and path forward for the four Renewing NSF pillars over the timeframe of the new Strategic Plan. For more information, see the Performance Chapter of this Request.

Performance Plan

NSF embraces the use of goals to drive performance improvements. For FY 2020, NSF has set performance goals to strategically monitor and oversee progress being made toward its larger aims, including support of the Big Ideas, as well as progress towards the agency reform plan, Renewing NSF. NSF will also assess progress through an annual process of strategic reviews of the objectives in its Strategic Plan.

In FY 2020, NSF will monitor the following goals:

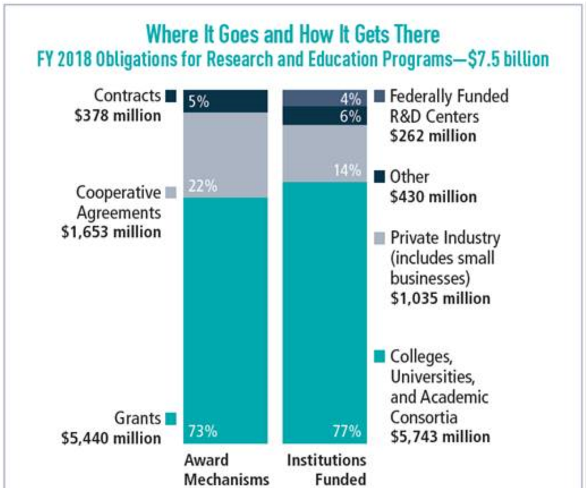
- **Ensure that Key Program Investments Are on Track:** Ensure that key FY 2020 NSF-wide program investments are implemented and on track.
- **Ensure that Infrastructure Investments Are on Track:** Ensure program integrity and responsible stewardship of major research facilities and infrastructure.
- **Make Timely Proposal Decisions:** 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.
- **Improve Review Quality:** Improve the quality of written reviews of NSF proposals.
- **Foster a Culture of Inclusion:** Foster a culture of inclusion through change management efforts resulting in change leadership and accountability.
- **Align Job Requirements with Competencies:** Ensure that employee job requirements are aligned with competencies and skills needed for the future.
- **Improve User Interactions with IT Systems:** Streamline and simplify user interactions with IT systems and functions that support the merit review process, reducing non-value-added steps and reducing the time spent managing the proposal and award lifecycle.

NSF will also set Agency Priority Goals in FY 2020 for achievement in FY 2021, which will support areas where focused, cross-cutting effort can produce impactful results in a short timeframe.

NSF by the Numbers

NSF by the Numbers: In FY 2020, NSF expects to evaluate approximately 46,100 proposals through a competitive merit review process and make approximately 10,400 new competitive awards, 8,000 of which will be new research grants and the remainder of which will be contracts and cooperative agreements. 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 involves approximately 224,000 proposal reviews, engaging on the order of 32,000 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 U.S. territories. In FY 2020, NSF support is expected to reach approximately 348,400 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 2018, it is expected that the relative shares in FY 2020 will be similar. As shown on the graph, 95 percent of NSF's FY 2018 projects were funded using grants or cooperative agreements. NSF grants are either standard or continuing awards. That is, the award is made during one fiscal year for the full amount of the award or made over several years in increments. Cooperative agreements are used when the project requires substantial agency involvement during the project performance period (e.g., research centers, major multi-user research facilities). Contracts are used to acquire products, services, and studies (e.g., program evaluations) required primarily for NSF or other government use.

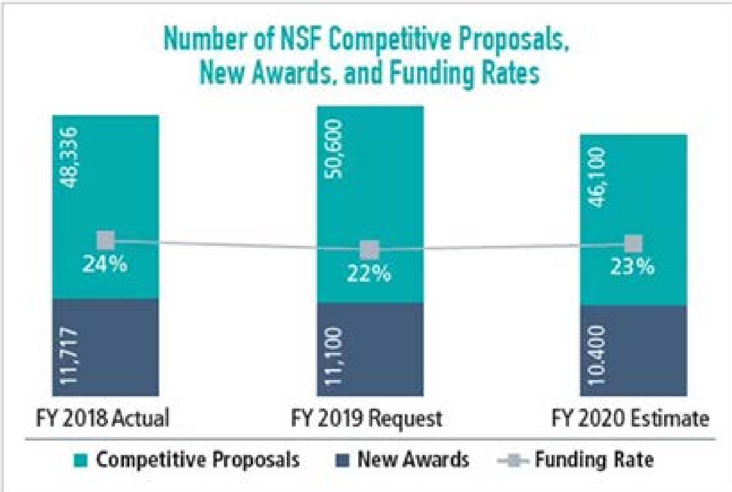


This chart shows the distribution of NSF's obligations by institution type and funding mechanism. While the data shown are based on FY 2018, the relative shares should provide a good indication of the FY 2020 distribution.

Note: NSF Research and Education Programs include R&RA, EHR, and MREFC appropriations. Other institutions funded include federal, state, and local governments; nonprofit organizations; and international organizations. Totals may not add due to rounding.

R&D = Research and Development

Most NSF awards are to academic institutions. As shown in the chart, 77 percent of support for research and education programs ($5,743 million) was to colleges (including two-year and community colleges), universities, and academic consortia. Private industry, including small businesses, accounted for 14 percent ($1,035 million), and support to Federally Funded Research and Development Centers (FFRDCs) accounted for four percent ($262 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.

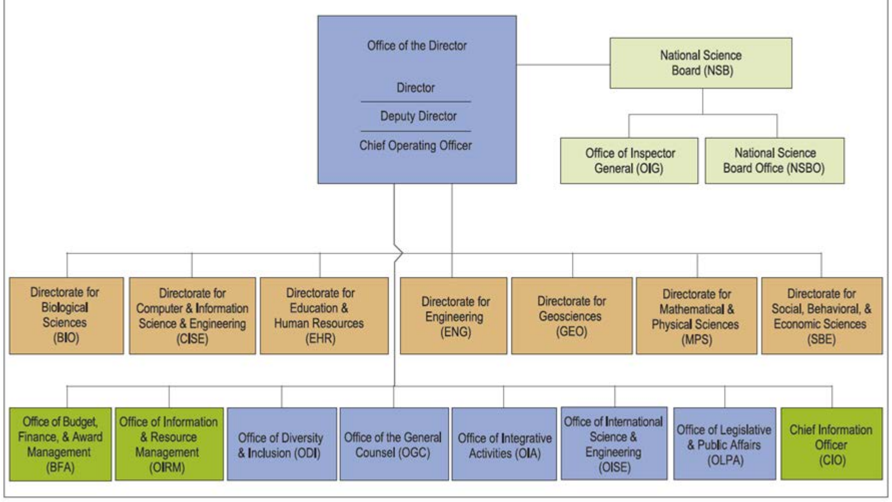


The chart on the left presents a high-level, agency-wide estimate of funding rates, or proposal "success," as a comparison of the number of competitive proposals, new awards, and funding rate between FY 2018, FY 2019, and FY 2020. In FY 2020, NSF expects to make approximately 10,400 new awards, which corresponds to a funding rate of about 23 percent.

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.

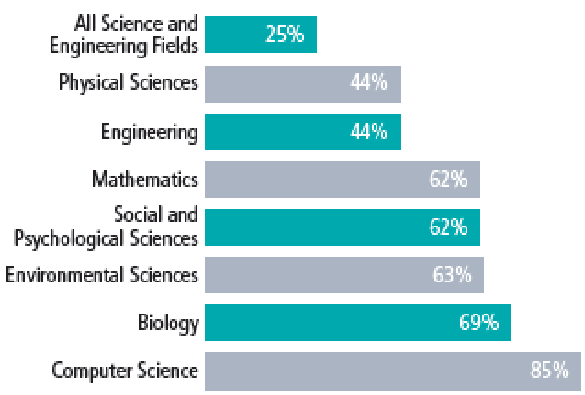
Figure 1.3
NSF FY 2018 Organization Chart



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 approves the overall policies of the Foundation.

NSF's annual budget represents approximately 25 percent of the total federal budget for basic research conducted at U.S. colleges and universities, and this share increases to approximately 59 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.

NSF Support of Academic Basic Research in Selected Fields
(as a percentage of total federal support)

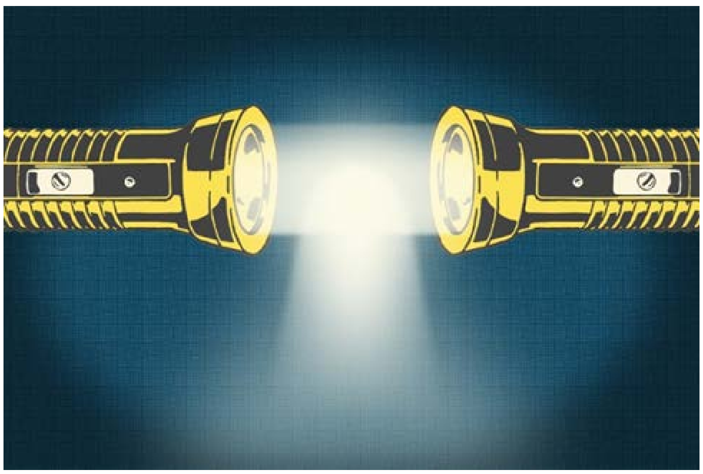


Note: Biology includes Biological Sciences and Environmental Biology. Biology and Psychological Sciences exclude National Institutes of Health funding from the total amount of federal support.
Source: NSF/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research & Development, FY 2016.

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 a few examples of the important advances that NSF funding enables.

New form of light could enable quantum computing



NSF-funded scientists have coaxed photons to interact, paving the way for their use in quantum computing.
Credit: Christine Daniloff/MIT

Extremely fast quantum computers will require the controlled interaction of light particles called photons. But photons don't naturally interact with each other. For years, physicists tested ways to encourage photon mingling. The efforts paid off in 2013 when NSF-funded researchers observed pairs of photons interacting and binding together. Now in 2018, the same scientists reported witnessing groups of three photons melding together. The behavior occurred during an experiment in which a very weak laser beam shone through a dense cloud of ultracold rubidium atoms. Rather than exiting the cloud singly, the photons left in pairs or triplets. The next step is to see if photons can interact in other ways. If successful, they may be harnessed to perform extremely fast, highly complex quantum computations.

Robotic float tracks ocean data

Southern Ocean data is critical to understanding how carbon dioxide interacts with the polar oceans. However, obtaining that data is challenging because the ocean is one of the world's most turbulent. To overcome this hurdle, NSF-funded researchers developed an array of robotic floats. Diving and drifting in the waters around Antarctica, the floats collect valuable details and beam their findings back to shore via satellite. A recent study using float data suggests that open water nearest the sea ice surrounding the southernmost continent releases significantly more carbon dioxide in winter than previously believed. By increasing the amount of data collected and its specificity, the floats are helping researchers refine carbon dioxide models and understand seasonal and multiyear trends.

Researchers drop a robotic float into the Southern Ocean.
Credit: Greta Shum, ClimateCentral

Highlights

NSF-funded research, supercomputer working to develop next generation batteries

Large-scale structures such as smart grids and wind turbines require next generation batteries with greater energy capacity than the lithium ion batteries found in today's smaller consumer electronics. One possible solution is lithium-metal batteries, which can store large amounts of energy at a low cost. These batteries have one key flaw, however: they are susceptible to dendritic growth, wherein lithium atoms clump together in the battery over its life cycle, leading to overheating, short-circuiting and even fire.

NSF-funded researchers are working to better understand how dendrites form and how new materials can prevent dendrite formation. Using powerful supercomputers, including the NSF-funded Stampede supercomputer operated by the Texas Advanced Computing Center, the researchers were able to model at the atomic level how a graphene oxide nanosheet, sprayed onto a glass fiber separator inserted into a lithium-metal battery, helped control the flow of ions and slow the build-up of lithium atoms in a battery, thus mitigating dendrite growth. Understanding how different coatings impact ion transfer could help researchers develop new materials to enhance the utility of lithium-metal batteries.

The Stampede supercomputer has already enabled research teams to predict where and when earthquakes may strike, how much sea levels could rise and how fast brain tumors grow.
Credit: University of Texas at Austin's Texas Advanced Computing Center

Artificial Intelligence research inspired by human visual learning accelerates drug discovery

NSF-funded researchers combined nuclear magnetic resonance spectroscopy with artificial intelligence (AI) to more quickly assess the uniqueness of natural compounds, from which new drugs are often derived. The researchers developed a deep learning system, called Small Molecule Accurate Recognition Technology (SMART), that could streamline by 10-fold the process of identifying the chemical structure of new compounds, leading to faster drug discovery. The tool embraces techniques developed from an NSF-funded researcher's work on face-recognition and visual expertise. It is an example of biologically-inspired machine learning, which is being used to help researchers analyze structures of new compounds.

Highlights

Advancing new drug therapies with light

NSF-funded researchers developed a biosensor that could help advance high-throughput testing for new drug evaluation. Made of a phosphorescent gel, the biosensor measures oxygen levels for organ-on-a-chip systems; these are small, biological structures that mimic a specific organ function. Monitoring oxygen levels is important because normal levels signal health and abnormal levels signal disease. Until the biosensor, researchers lacked tools to retrieve data from the chip systems in real time. Now, rather than destroying the tissue, researchers can flash infrared light at the biosensor. In response, the sensor emits its own infrared light, depending on the oxygen level. Lag times last just microseconds, but with them researchers can measure oxygen concentrations down to tenths of a percent.

This biosensor tracks oxygen levels using infrared light.
Credit: Kristina Rivera, NCSU/UNC

Training students for the growing unmanned aircraft systems market

Instruction for faculty participants.
Credit: Chris Carter, Virginia Space Grant Consortium

Through the NSF-funded Geospatial Technician Education-Unmanned Aircraft Systems Faculty Institute, high school teachers and faculty members are learning how to plan and fly manual and autonomous unmanned aircraft system (UAS) missions. The week-long training enables the educators to establish coursework for Virginia's community colleges. Thus far, the project helped five colleges in the Virginia Community College System to offer UAS courses for credit, and three additional colleges to offer non-credit courses. NSF's Advanced Technological Education Program funds the UAS training activity, with the goal of promoting the education of technicians to meet STEM workforce demands through faculty professional development, curriculum development and precollege activities at 2-year colleges. More than 200 students completed courses at one school, Mountain Empire Community College. The project seeks to meet the emerging demand for trained UAS technicians. In 2013, the Association for Unmanned Vehicle Systems International released a report that projected more than 100,000 new jobs in UAS by 2025.

Highlights

Engineered sand zaps stormwater pollutants

Using a mineral-coated sand that reacts with and destroys organic pollutants, NSF-funded researchers have discovered that the engineered sand could help purify stormwater percolating into underground aquifers. The discovery may lead to a safe and local reservoir of drinking water for communities in need of clean water sources. As utilities in water-stressed regions consider how to direct urban stormwater back into the ground, water quality becomes a concern. The coated sand is an inexpensive option for removing many of the contaminants that pose risks to groundwater systems. Although the coating does not remove all pollutants, it can be used in conjunction with other water purification systems to remove most impurities.

Engineered sand destroys toxins such as endocrine-disrupting bisphenol A (BPA).
Credit: Kara Manke

NSF-funded researcher "transfers" a memory

"I think in the not-too-distant future, we could potentially use RNA to ameliorate the effects of Alzheimer's disease or post-traumatic stress disorder," said UCLA professor David Glanzman, seen here holding a marine snail.
Credit: Christelle Snow, UCLA

An NSF-funded researcher reported that his team transferred a memory from one animal to another via injections of ribonucleic acid, or RNA, extracted from the first animal's neurons. The results challenge the way scientists understand where and how the brain stores memories and hints at the potential for new RNA-based treatments to one day restore lost memories or treat post-traumatic stress disorder. The results also indicate that memory storage involves RNA-mediated epigenetic changes, or changes in the activity of genes, and not in the DNA sequences that make up those genes. The findings potentially upset the long-held idea in neuroscience that memories are stored in the brain's synapses, which convey electrical or chemical signals between nerve cells. Instead, the new research suggests that memories may in fact be stored in neurons' nuclei, a finding that has implications in both the basic sciences and the clinical realm.

SUMMARY TABLES

NATIONAL SCIENCE FOUNDATION
SUMMARY TABLE
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

NSF by Account	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted[2]	FY 2020 Request	FY 2020 Request change over FY 2018 Actual: Amount	FY 2020 Request change over FY 2018 Actual: Percent
BIO	$756.60	-	-	$683.36	-$73.24	-9.7%
CISE	960.80	-	-	883.04	-77.76	-8.1%
ENG	977.90	-	-	881.42	-96.48	-9.9%
Eng Programs	*767.92*	-	-	*686.27*	*-81.65*	*-10.6%*
SBIR/STTR, including Operations	*209.98*	-	-	*195.15*	*-14.83*	*-7.1%*
GEO	907.80	-	-	787.05	-120.75	-13.3%
MPS	1,503.41	-	-	1,255.82	-247.59	-16.5%
SBE	250.69	-	-	230.08	-20.61	-8.2%
OISE	48.98	-	-	46.24	-2.74	-5.6%
OPP	501.72	-	-	403.39	-98.33	-19.6%
U.S. Antarctic Logistics Activities	*71.13*	-	-	*71.00*	*-0.13*	*-0.2%*
Other Polar Programs	*430.59*	-	-	*332.39*	*-98.20*	*-22.8%*
IA	471.05	-	-	491.04	19.99	4.2%
U.S. Arctic Research Commission	1.43	-	-	1.52	0.09	6.3%
Research & Related Activities	**$6,380.38**	**$6,334.48**	**$6,520.00**	**$5,662.96**	**-$717.42**	**-11.2%**
Education & Human Resources	**$903.87**	**$902.00**	**$910.00**	**$823.47**	**-$80.40**	**-8.9%**
Major Research Equipment & Facilities Construction	**$186.30**	**$182.80**	**$295.74**	**$223.23**	**$36.93**	**19.8%**
Agency Operations & Award Management	**$328.51**	**$328.51**	**$329.54**	**$336.89**	**$8.38**	**2.6%**
National Science Board	**$4.30**	**$4.37**	**$4.37**	**$4.10**	**-$0.20**	**-4.6%**
Office of Inspector General	**$15.09**	**$15.20**	**$15.35**	**$15.35**	**$0.26**	**1.7%**
Total, NSF Discretionary Funding	**$7,818.43**	**$7,767.36**	**$8,075.00**	**$7,066.00**	**-$752.43**	**-9.6%**
Education and Human Resources - H-1B Visa	192.26	192.23	192.23	120.00	-72.26	-37.6%
Donations	29.22	71.76	71.76	40.00	10.78	36.9%
Total, NSF Mandatory Funding	**$221.48**	**$263.99**	**$263.99**	**$160.00**	**-$61.48**	**-27.8%**
Total, NSF Budgetary Resources	**$8,039.91**	**$8,031.35**	**$8,338.99**	**$7,226.00**	**-$813.91**	**-10.1%**

Totals exclude reimbursable amounts.

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

[2] Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.

NSF FUNDING PROFILE

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

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

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

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

NSF Funding Profile[1]

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Request Estimate
Statistics for Competitive Awards			
Number of Proposals	48,100	-	46,100
Number of Awards	11,600	-	10,400
Funding Rate	24%	-	23%
Statistics for Research Grant Awards			
Number of Research Grant Proposals	40,300	-	38,700
Number of Research Grant Awards	9,000	-	8,000
Funding Rate	22%	-	21%
Median Annualized Award Size	$152,600	-	$145,700
Average Annualized Award Size	$182,100	-	$179,900
Average Duration (years)	3.0	-	3.0

[1] Display excludes NSB, OIG, and staff offices.

NUMBER OF PEOPLE INVOLVED IN NSF ACTIVITIES

NSF estimates that in FY 2020 approximately 348,400 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 2020 Request
Number of People Involved in NSF Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	44,136	-	39,850
Other Professionals	14,333	-	12,640
Postdoctoral Associates	5,979	-	5,270
Graduate Students	41,874	-	38,000
Undergraduate Students	37,669	-	35,040
K-12 Teachers	41,945	-	38,200
K-12 Students	199,931	-	179,400
Total Number of People	**385,867**	**-**	**348,400**

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. These individuals are supported through funds included in research projects, centers, or facilities awards, as well as by postdoctoral fellowships.

Graduate Students include those compensated from NSF grant funds. Approximately 18 percent receive support through NSF's fellowship and traineeship programs. Other graduate students 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 32 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 2018: Chapter 2 Higher Education in Science and Engineering, Appendix Tables 02-08 and 02-13. Retrieved from www.nsf.gov/statistics/2018/nsb20181/data/appendix?achapter561

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 2020

(Millions of Current Dollars)

Click here for complete history

	Research & Related Activities (R&RA)		Education & Human Resources (EHR)		Major Research Equipment & Facilities Construction (MREFC)[1]		Agency Operations & Award Management (AOAM)[2]		Office of Inspector General (OIG)		National Science Board (NSB)		NSF, TOTAL	
Fiscal Year	**Request**	**Appropriation**	**Request**	**Appropriation**	**Request**	**Appropriation**	**Request**	**Appropriation**	**Request**	**Appropriation**	**Request**	**Appropriation**	**Request**	**Appropriation**
2000	$3,004.00	$2,972.90	$678.00	$690.87	$85.00	$93.50	$149.00	$149.28	$5.45	$5.45	-	-	$3,921.45	$3,912.00
2001	3,540.68	3,356.29	729.01	785.60	138.54	121.33	157.89	161.09	6.28	6.27	-	-	4,572.40	4,430.57
2002	3,326.98	3,612.26	872.41	894.28	96.33	138.80	170.04	171.26	6.76	6.75	-	-	4,472.52	4,823.35
2003	3,783.21	4,069.29	908.08	903.17	126.28	148.54	210.16	189.43	8.06	9.19	-	3.48	5,035.79	5,323.09
2004	4,106.36	4,262.12	938.04	938.98	202.33	154.98	225.70	218.96	8.77	9.94	-	3.88	5,481.20	5,588.86
2005	4,452.31	4,229.98	771.36	841.42	213.27	173.65	294.00	223.45	10.11	10.03	3.95	3.97	5,745.00	5,482.49
2006	4,333.49	4,339.21	737.00	796.69	250.01	190.88	269.00	247.06	11.50	11.35	4.00	3.95	5,605.00	5,589.14
2007	4,665.95	4,654.24	816.22	796.59	240.45	175.61	281.82	248.50	11.86	10.97	3.91	3.97	6,020.21	5,889.87
2008	5,131.69	4,841.73	750.60	765.60	244.74	220.74	285.59	281.79	12.35	11.43	4.03	3.97	6,429.00	6,125.26
2009	*5,593.99*	*5,186.17*	*790.41*	*845.26*	*147.51*	*152.01*	*305.06*	*294.15*	*13.10*	*12.00*	*4.03*	*4.03*	*6,854.10*	*6,493.61*
2009 ARRA	-	*2,500.00*	-	*100.00*	-	*400.00*		-	-	*2.00*		-	-	*3,002.00*
2009 Total	5,593.99	7,686.17	790.41	945.26	147.51	552.01	305.06	294.15	13.10	14.00	4.03	4.03	6,854.10	9,495.61
2010	5,733.24	5,563.92	857.76	872.76	117.29	117.29	318.37	300.00	14.00	14.00	4.34	4.54	7,045.00	6,872.51
2011	6,018.83	5,509.98	892.00	861.03	165.19	117.06	329.19	299.40	14.35	13.97	4.84	4.53	7,424.40	6,805.98
2012	6,253.54	5,689.00	911.20	829.00	224.68	197.06	357.74	299.40	15.00	14.20	4.84	4.44	7,767.00	7,033.10
2013	5,983.28	5,543.72	875.61	833.31	196.17	196.17	299.40	293.60	14.20	13.19	4.44	4.12	7,373.10	6,884.11
2014	6,212.29	5,808.92	880.29	846.50	210.12	200.00	304.29	298.00	14.32	14.20	4.47	4.30	7,625.78	7,171.92
2015	5,807.46	5,933.65	889.75	866.00	200.76	200.76	338.23	325.00	14.43	14.43	4.37	4.37	7,255.00	7,344.21
2016	6,186.30	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	6,425.44	6,005.65	952.86	873.05	193.12	214.86	373.02	359.09	15.20	15.20	4.38	4.37	7,964.02	7,472.22
2018[3]	5,361.65	6,334.48	760.55	902.00	182.80	182.80	328.51	328.51	15.01	15.20	4.37	4.37	6,652.89	7,767.36
2019[4]	6,150.68	6,520.00	873.37	910.00	94.65	295.74	333.63	329.54	15.35	15.35	4.32	4.37	7,472.00	8,075.00
2020	5,662.96	-	823.47	-	223.23	-	336.89	-	15.35	-	4.10	-	7,066.00	-

Appropriations as shown are after supplemental appropriations, transfers, and reprogrammings.

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

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

[3] FY 2018 appropriations include Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123), which provided NSF $16.30 million in no-year funding to repair radio observatory facilities damaged by hurricanes that occurred during 2017.

[4] FY 2019 Appropriations are Enacted appropriations.

NATIONAL SCIENCE FOUNDATION
CONVERGENCE ACCELERATORS AND NSF 10 BIG IDEAS FUNDING
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

Convergence Accelerators and Big Ideas	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Convergence Accelerators	**-**	**-**	**$60.00**
Harnessing the Data Revolution for 21st Century Science and Engineering (HDR)	-	-	30.00
The Future of Work at the Human-Technology Frontier (FW-HTF)	-	-	30.00
Research Ideas	**-**	**-**	**$180.00**
Harnessing the Data Revolution for 21st Century Science and Engineering (HDR)	-	-	30.00
The Future of Work at the Human-Technology Frontier (FW-HTF)	-	-	30.00
Navigating the New Arctic (NNA)	-	-	30.00
The Quantum Leap (QL)	-	-	30.00
Understanding the Rules of Life (URoL)	-	-	30.00
Windows on the Universe (WoU)	-	-	30.00
Enabling Big Ideas	**$22.95**	**-**	**$117.50**
Growing Convergence Research (GCR)	5.00	-	16.00
Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	17.95	-	20.00
Mid-scale Research Infrastructure	-	-	75.00
NSF 2026	-	-	6.50
Total, NSF Convergence Accelerators and Big Ideas	**$22.95**	-	**$357.50**

NATIONAL SCIENCE FOUNDATION
SELECTED CROSSCUTTING PROGRAMS
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

Selected Cross-Cutting Programs		**FY 2018 Actual**	**FY 2019 (TBD)**	**FY 2020 Request**	**FY 2020 Request change over FY 2018 Actual Amount**	**Percent**
ADVANCE	Research & Related Activities	16.47	-	-	-16.47	-100.0%
	Education & Human Resources	1.53	-	18.00	16.47	1076.5%
	Total, NSF	**$18.00**	**-**	**$18.00**	**-**	**-**
Faculty Early Career Development - CAREER	Research & Related Activities	287.15	-	249.14	-38.01	-13.2%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$287.15**	**-**	**$249.14**	**-$38.01**	**-13.2%**
Long-Term Ecological Research Sites - LTERs	Research & Related Activities	29.46	-	28.43	-1.03	-3.5%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$29.46**	**-**	**$28.43**	**-$1.03**	**-3.5%**
Research Experiences for Undergraduates - REU - Sites Only	Research & Related Activities	65.94	-	57.90	-8.04	-12.2%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$65.94**	**-**	**$57.90**	**-$8.04**	**-12.2%**
Research Experiences for Undergraduates - REU - Supplements Only	Research & Related Activities	21.55	-	18.47	-3.08	-14.3%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$21.55**	**-**	**$18.47**	**-$3.08**	**-14.3%**
Total, Research Experiences for Undergraduates - REU	Research & Related Activities	87.49	-	76.37	-11.12	-12.7%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$87.49**	**-**	**$76.37**	**-$11.12**	**-12.7%**
Research in Disabilities Education - RDE	Research & Related Activities	0.16	-	-	-0.16	-100.0%
	Education & Human Resources	12.45	-	6.50	-5.95	-47.8%
	Total, NSF	**$12.61**	**-**	**$6.50**	**-$6.11**	**-48.5%**
Research in Undergraduate Institutions - RUI	Research & Related Activities	48.02	-	34.49	-13.53	-28.2%
	Education & Human Resources	-	-	-	-	N/A
	Total, NSF	**$48.02**	**-**	**$34.49**	**-$13.53**	**-28.2%**

NATIONAL SCIENCE FOUNDATION
NSTC CROSSCUTS SUMMARY
FY 2020 BUDGET REQUEST
(Dollars in Millions)

	National Nanotechnology Initiative (NNI)				
	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
BIO	$42.50	-	$42.50	-	-
CISE	15.68	-	14.05	-1.63	-10.4%
ENG	206.00	-	168.50	-37.50	-18.2%
MPS	300.14	-	161.84	-138.30	-46.1%
SBE	0.40	-	-	-0.40	-100.0%
OISE	0.10	-	-	-0.10	-100.0%
R&RA	**$564.82**	**-**	**$386.89**	**-$177.93**	**-31.5%**
EHR	**$3.20**	**-**	**$2.50**	**-$0.70**	**-21.9%**
NSF Total	**$568.02**	**-**	**$389.39**	**-$178.63**	**-31.4%**

	Networking & Information Technology R&D (NITRD)				
	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
BIO	$93.50	-	$79.00	-$14.50	-15.5%
CISE	960.80	-	883.04	-77.76	-8.1%
ENG	32.59	-	33.35	0.76	2.3%
GEO	24.00	-	20.00	-4.00	-16.7%
MPS	152.34	-	149.47	-2.87	-1.9%
SBE	22.84	-	22.97	0.13	0.6%
R&RA	**$1,286.07**	**-**	**$1,187.83**	**-$98.24**	**-7.6%**
EHR	**$9.50**	**-**	**$9.50**	**-**	**-**
NSF Total	**$1,295.57**	**-**	**$1,197.33**	**-$98.24**	**-7.6%**

	U.S. Global Change Research Program (USGCRP)				
	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
BIO	$94.00	-	$87.60	-$6.40	-6.8%
GEO	130.00	-	113.00	-17.00	-13.1%
SBE	14.98	-	12.46	-2.52	-16.8%
OPP	15.15	-	11.04	-4.11	-27.1%
R&RA	**$254.13**	**-**	**$224.10**	**-$30.03**	**-11.8%**
EHR	**-**	**-**	**-**	**-**	**N/A**
NSF Total	**$254.13**	**-**	**$224.10**	**-$30.03**	**-11.8%**

NATIONAL SCIENCE FOUNDATION
NATIONAL NANOTECHNOLOGY INITIATIVE SUMMARY
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	BIO	CISE	ENG	GEO	MPS	SBE	OISE	RRA	EHR	Total, NSF
Total, FY 2018 Actual	**$42.50**	**$15.68**	**$206.00**	**-**	**$300.14**	**$0.40**	**$0.10**	**$564.82**	**$3.20**	**$568.02**
NNI Grand Challenge (GC) and Signature Initiative (NSI) Total	-	4.40	104.50	-	58.79	-	-	167.69	-	167.69
Nanotechnology-Inspired Grand Challenge for Future Computing	-	*4.40*	*7.00*	-	-	-	-	*11.40*	-	*11.40*
Nanoelectronics for 2020 and Beyond	-	-	*31.50*	-	*42.95*	-	-	*74.45*	-	*74.45*
Nanotechnology for Sensors and Sensors for Nanotechnology	-	-	*9.50*	-	*4.65*	-	-	*14.15*	-	*14.15*
Nanotechnology Knowledge Infrastructure	-	-	*15.00*	-	*5.21*	-	-	*20.21*	-	*20.21*
Sustainable Nanomanufacturing	-	-	*30.00*	-	*5.89*	-	-	*35.89*	-	*35.89*
Water Sustainability through Nanotechnology	-	-	*11.50*	-	*0.09*	-	-	*11.59*	-	*11.59*
Environment, Health, and Safety	-	0.31	9.00	-	3.23	-	-	12.54	-	12.54
Foundational Research	40.00	6.79	34.00	-	211.52	-	-	292.31	-	292.31
Nanotechnology-Enabled Applications, Devices, and Systems	-	2.08	38.50	-	9.33	-	-	49.91	-	49.91
Research Infrastructure and Instrumentation	2.50	2.10	20.00	-	17.26	0.40	0.10	42.36	3.20	45.56
Delta from FY 2018 Actual to FY 2020 Request	**-**	**-$1.63**	**-$37.50**	**-**	**-$138.30**	**-$0.40**	**-$0.10**	**-$177.93**	**-$0.70**	**-$178.63**
NNI Grand Challenge (GC) and Signature Initiative (NSI) Total	-	-0.40	-36.00	-	-39.79	-	-	-76.19	-	-76.19
Nanotechnology-Inspired Grand Challenge for Future Computing	-	*-0.40*	*1.00*	-	*1.00*	-	-	*1.60*	-	*1.60*
Nanoelectronics for 2020 and Beyond	-	-	*-13.00*	-	*-29.45*	-	-	*-42.45*	-	*-42.45*
Nanotechnology for Sensors and Sensors for Nanotechnology	-	-	*-3.50*	-	*-3.15*	-	-	*-6.65*	-	*-6.65*
Nanotechnology Knowledge Infrastructure	-	-	*-15.00*	-	*-5.21*	-	-	*-20.21*	-	*-20.21*
Sustainable Nanomanufacturing	-	-	*-4.00*	-	*-3.89*	-	-	*-7.89*	-	*-7.89*
Water Sustainability through Nanotechnology	-	-	*-1.50*	-	*0.91*	-	-	*-0.59*	-	*-0.59*
Environment, Health, and Safety	-	-0.31	-	-	-1.68	-	-	-1.99	-	-1.99
Foundational Research	-	-0.54	13.00	-	-97.30	-	-	-84.84	-	-84.84
Nanotechnology-Enabled Applications, Devices, and Systems	-	-0.18	-6.50	-	-5.33	-	-	-12.01	-	-12.01
Research Infrastructure and Instrumentation	-	-0.20	-8.00	-	5.81	-0.40	-0.10	-2.89	-0.70	-3.59
Total, FY 2020 Request	**$42.50**	**$14.05**	**$168.50**	**-**	**$161.84**	**-**	**-**	**$386.89**	**$2.50**	**$389.39**
NNI Grand Challenge (GC) and Signature Initiative (NSI) Total	-	4.00	68.50	-	19.00	-	-	91.50	-	91.50
Nanotechnology-Inspired Grand Challenge for Future Computing	-	*4.00*	*8.00*	-	*1.00*	-	-	*13.00*	-	*13.00*
Nanoelectronics for 2020 and Beyond	-	-	*18.50*	-	*13.50*	-	-	*32.00*	-	*32.00*
Nanotechnology for Sensors and Sensors for Nanotechnology	-	-	*6.00*	-	*1.50*	-	-	*7.50*	-	*7.50*
Nanotechnology Knowledge Infrastructure	-	-	-	-	-	-	-	-	-	-
Sustainable Nanomanufacturing	-	-	*26.00*	-	*2.00*	-	-	*28.00*	-	*28.00*
Water Sustainability through Nanotechnology	-	-	*10.00*	-	*1.00*	-	-	*11.00*	-	*11.00*
Environment, Health, and Safety	-	-	9.00	-	1.55	-	-	10.55	-	10.55
Foundational Research	40.00	6.25	47.00	-	114.22	-	-	207.47	-	207.47
Nanotechnology-Enabled Applications, Devices, and Systems	-	1.90	32.00	-	4.00	-	-	37.90	-	37.90
Research Infrastructure and Instrumentation	2.50	1.90	12.00	-	23.07	-	-	39.47	2.50	41.97

NATIONAL SCIENCE FOUNDATION
NETWORKING AND INFORMATION TECHNOLOGY R&D SUMMARY
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	BIO	CISE	ENG	GEO	MPS	SBE	RRA	EHR	Total, NSF
Total, FY 2018 Actual	**$93.50**	**$960.80**	**$32.59**	**$24.00**	**$152.34**	**$22.84**	**$1,286.07**	**$9.50**	**$1,295.57**
Artificial Intelligence	15.00	133.21	10.57	-	25.51	0.22	184.51	-	184.51
Computing-Enabled Human Interaction, Communications, Augmentation	18.00	67.17	6.86	-	2.53	10.29	104.85	-	104.85
Computing-Enabled Networked Physical Systems	1.00	63.08	3.64	-	-	-	67.72	-	67.72
Cyber Security & Privacy	-	97.86	-	-	0.11	6.02	103.99	-	103.99
Education and Workforce	6.00	60.01	-	-	-	-	66.01	9.50	75.51
Enabling-R&D for High-Capability Computing System	-	100.77	-	-	77.40	-	178.17	-	178.17
High Capability Computing Infrastructure and Applications	2.50	109.19	-	24.00	42.15	-	177.84	-	177.84
Intelligent Robotics and Autonomous Systems	-	30.11	8.10	-	-	-	38.21	-	38.21
Large-Scale Data Management and Analysis	36.50	117.62	3.42	-	4.64	4.98	167.16	-	167.16
Large Scale Networking	-	128.05	-	-	-	-	128.05	-	128.05
Software Productivity, Sustainability and Quality	14.50	53.73	-	-	-	1.33	69.56	-	69.56
Delta from FY 2018 Actual to FY 2020 Request	**-$14.50**	**-$77.76**	**$0.76**	**-$4.00**	**-$2.87**	**$0.13**	**-$98.24**	**-**	**-$98.24**
Artificial Intelligence	-3.00	5.37	0.18	-	6.82	-	9.37	-	9.37
Computing-Enabled Human Interaction, Communications, Augmentation	-18.00	-5.67	-0.11	-	-2.53	-1.38	-27.69	-	-27.69
Computing-Enabled Networked Physical Systems	-	-5.33	-0.04	-	-	-	-5.37	-	-5.37
Cyber Security & Privacy	-	-7.66	1.00	-	0.89	-2.02	-7.79	-	-7.79
Education and Workforce	-	-19.81	-	-	-	-	-19.81	-	-19.81
Enabling-R&D for High-Capability Computing System	-	-8.47	-	-	-10.40	-	-18.87	-	-18.87
High Capability Computing Infrastructure and Applications	-	-9.19	-	-4.00	-4.15	-	-17.34	-	-17.34
Intelligent Robotics and Autonomous Systems	-	-2.35	0.15	-	-	-	-2.20	-	-2.20
Large-Scale Data Management and Analysis	6.50	-9.32	-0.42	-	6.50	2.94	6.20	-	6.20
Large Scale Networking	-	-10.80	-	-	-	-	-10.80	-	-10.80
Software Productivity, Sustainability and Quality	-	-4.53	-	-	-	0.59	-3.94	-	-3.94
Total, FY 2020 Request	**$79.00**	**$883.04**	**$33.35**	**$20.00**	**$149.47**	**$22.97**	**$1,187.83**	**$9.50**	**$1,197.33**
Artificial Intelligence	12.00	138.58	10.75	-	32.33	0.22	193.88	-	193.88
Computing-Enabled Human Interaction, Communications, Augmentation	-	61.50	6.75	-	-	8.91	77.16	-	77.16
Computing-Enabled Networked Physical Systems	1.00	57.75	3.60	-	-	-	62.35	-	62.35
Cyber Security & Privacy	-	90.20	1.00	-	1.00	4.00	96.20	-	96.20
Education and Workforce	6.00	40.20	-	-	-	-	46.20	9.50	55.70
Enabling-R&D for High-Capability Computing System	-	92.30	-	-	67.00	-	159.30	-	159.30
High Capability Computing Infrastructure and Applications	2.50	100.00	-	20.00	38.00	-	160.50	-	160.50
Intelligent Robotics and Autonomous Systems	-	27.76	8.25	-	-	-	36.01	-	36.01
Large-Scale Data Management and Analysis	43.00	108.30	3.00	-	11.14	7.92	173.36	-	173.36
Large Scale Networking	-	117.25	-	-	-	-	117.25	-	117.25
Software Productivity, Sustainability and Quality	14.50	49.20	-	-	-	1.92	65.62	-	65.62

NATIONAL SCIENCE FOUNDATION
U.S. GLOBAL CHANGE RESEARCH PROGRAM SUMMARY
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	BIO	CISE	ENG	GEO	MPS	SBE	OISE	OPP	RRA	EHR	Total, NSF
Total, FY 2018 Actual	**$94.00**	**-**	**-**	**$130.00**	**-**	**$14.98**	**-**	**$15.15**	**$254.13**	**-**	**$254.13**
Communication and Education	-	-	-	-	-	-	-	-	-	-	-
Integrated Modeling	-	-	-	22.00	-	3.50	-	3.28	28.78	-	28.78
Integrated Observations	65.00	-	-	20.00	-	-	-	5.00	90.00	-	90.00
Multidisciplinary Earth and Human System Understanding	29.00	-	-	82.00	-	3.73	-	6.87	121.60	-	121.60
Science of Adaptation and Science to Inform Adaptation Decisions	-	-	-	6.00	-	7.75	-	-	13.75	-	13.75
Delta from FY 2018 Actual to FY 2020 Request	**-$6.40**	**-**	**-**	**-$17.00**	**-**	**-$2.52**	**-**	**-$4.11**	**-$30.03**	**-**	**-$30.03**
Communication and Education	-	-	-	-	-	-	-	-	-	-	-
Integrated Modeling	-	-	-	-2.00	-	-	-	-0.89	-2.89	-	-2.89
Integrated Observations	-2.40	-	-	-3.00	-	-	-	-1.36	-6.76	-	-6.76
Multidisciplinary Earth and Human System Understanding	-4.00	-	-	-12.00	-	-	-	-1.86	-17.86	-	-17.86
Science of Adaptation and Science to Inform Adaptation Decisions	-	-	-	-	-	-2.52	-	-	-2.52	-	-2.52
Total, FY 2020 Request	**$87.60**	**-**	**-**	**$113.00**	**-**	**$12.46**	**-**	**$11.04**	**$224.10**	**-**	**$224.10**
Communication and Education	-	-	-	-	-	-	-	-	-	-	-
Integrated Modeling	-	-	-	20.00	-	3.50	-	2.39	25.89	-	25.89
Integrated Observations	62.60	-	-	17.00	-	-	-	3.64	83.24	-	83.24
Multidisciplinary Earth and Human System Understanding	25.00	-	-	70.00	-	3.73	-	5.01	103.74	-	103.74
Science of Adaptation and Science to Inform Adaptation Decisions	-	-	-	6.00	-	5.23	-	-	11.23	-	11.23

NATIONAL SCIENCE FOUNDATION
PROGRAMS TO BROADEN PARTICIPATION
FY 2020 BUDGET REQUEST TO CONGRESS

(Dollars in Millions)

Group/Program	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual: Amount	Percent
Total, NSF Broadening Participation Programs	**$1,004.08**	**-**	**$836.17**	**-$167.91**	**-16.7%**

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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual: Amount	Percent
ADVANCE	100%	$18.00	-	$18.00	-	-
Alliances for Graduate Education & the Professoriate (AGEP)	100%	8.00	-	7.54	-0.46	-5.8%
AGEP Graduate Research Supplements (AGEP-GRS)	100%	2.18	-	1.76	-0.42	-19.2%
Broadening Participation in Biology Fellowships	100%	3.24	-	2.50	-0.74	-22.8%
Broadening Participation in Engineering (BPE)	100%	6.56	-	6.58	0.02	0.3%
Career-Life Balance (CLB)	100%	0.40	-	0.32	-0.08	-20.7%
Centers of Research Excellence in Science & Technology (CREST)	100%	24.01	-	22.63	-1.38	-5.7%
Excellence Awards in Science & Engineering (EASE)[1]	100%	5.74	-	4.00	-1.74	-30.3%
Historically Black Colleges & Universities Undergraduate Program (HBCU-UP)	100%	34.92	-	33.00	-1.92	-5.5%
HBCU Excellence in Research (HBCU-EiR)[2]	100%	20.35	-	10.00	-10.35	-50.9%
Improving Undergraduate STEM Education (IUSE): Hispanic Serving Institutions (HSI) program[3]	100%	44.85	-	15.00	-29.85	-66.6%
Big Idea: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)	100%	17.95	-	20.00	2.05	11.4%
Louis Stokes Alliances for Minority Participation (LSAMP)	100%	46.02	-	46.00	-0.02	-0.0%
Partnerships for Research & Education in Materials (PREM)	100%	7.88	-	7.00	-0.88	-11.1%
Partnerships in Astronomy & Astrophysics Research Education (PAARE)	100%	1.11	-	-	-1.11	-100.0%
SBE Postdoctoral Research Fellowships-Broadening Participation	100%	1.47	-	1.50	0.03	1.8%
Science of Broadening Participation	100%	1.50	-	1.50	-	-
Tribal Colleges & Universities Program (TCUP)	100%	14.00	-	13.20	-0.80	-5.7%
Subtotal, Focused Programs		**$258.18**	**-**	**$210.53**	**-$47.65**	**-18.5%**

[1] The 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).

[2] In FY 2017, the HBCU-EiR Program was funded at $10.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($20.35 million).

[3] In FY 2017, the HSI Program was funded at $15.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($15.03 million).

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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual	
					Amount	Percent
Advancing Informal STEM Learning (AISL)	55%	$34.17	-	$32.42	-$1.75	-5.1%
Computer Science for All (CSforAll)[4]	51%	*[10.24]*	-	10.24	-	-
Disability and Rehabilitation Engineering (DARE)	66%	3.57	-	3.30	-0.27	-7.6%
Discovery Research PreK-12 (DRK-12)	62%	54.66	-	58.62	3.95	7.2%
Graduate Research Fellowship Program (GRFP)	64%	183.44	-	165.44	-18.00	-9.8%
Improving Undergraduate STEM Education (IUSE)	61%	60.56	-	56.90	-3.66	-6.0%
Innovative Technology Experiences for Students and Teachers (ITEST)[5]	59%	21.16	-	17.70	-3.46	-16.4%
International Research Experiences for Students (IRES)	51%	5.84	-	6.62	0.78	13.3%
NSF Scholarships in STEM (S-STEM)[5]	57%	89.14	-	51.30	-37.84	-42.5%
Research Experiences for Undergraduates (REU) - Sites and Supplements	59%	51.71	-	45.13	-6.57	-12.7%
Robert Noyce Teacher Scholarship Program (NOYCE)	57%	36.70	-	26.74	-9.96	-27.1%
STEM + Computing Partnerships (STEM+C Partnerships)[4]	53%	34.35	-	-	-34.35	-100.0%
Subtotal, Emphasis Programs		**$575.31**	**-**	**$474.41**	**-$100.90**	**-17.5%**

[4] In FY 2018, $10.0 million in EHR funding for CSforAll was supported as a component of STEM+C and $10.0 million in R&RA funding was provided by CISE. The total FY 2018 Actual is shown for comparison purposes only. In FY 2020, CISE continues its investment in CSforAll. Within EHR in FY 2020, funding for STEM+C moves to implement CSforAll as a freestanding program and to expand EHR's computer science education portfolio through existing programs.

[5] ITEST and S-STEM are H1B Visa funded programs.

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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual: Amount	FY 2020 Request change over FY 2018 Actual: Percent
EPSCoR	100%	$170.59	-	$151.23	-$19.36	-11.3%
Subtotal, Geographic Diversity Program		**$170.59**	**-**	**$151.23**	**-$19.36**	**-11.3%**

NATIONAL SCIENCE FOUNDATION
EDUCATION AND HUMAN RESOURCES FUNDING BY DIVISION AND PROGRAM
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual: Amount	Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	**$228.22**	**-**	**$181.72**	**-$46.50**	**-20.4%**
Learning and Learning Environments	**25.63**	**-**	**27.78**	**2.15**	**8.4%**
Computer Science for All (CSforAll)[1]	*[10.00]*	-	10.00	-	-
EHR Core Research (ECR): STEM Learning	25.63	-	17.78	-7.85	-30.6%
Broadening Participation and Institutional Capacity	**150.72**	**-**	**153.94**	**3.22**	**2.1%**
Advancing Informal STEM Learning (AISL)	62.13	-	58.94	-3.19	-5.1%
Discovery Research PreK-12 (DRK-12)	88.59	-	95.00	6.41	7.2%
STEM Professional Workforce	**51.87**	**-**	**-**	**-51.87**	**-100.0%**
Science, Technology, Engineering, and Mathematics + Computing (STEM+C) Partnerships[1]	51.87	-	-	-51.87	-100.0%
Division of Graduate Education (DGE)	**$258.34**	**-**	**$244.06**	**-$14.28**	**-5.5%**
Learning and Learning Environments	**7.57**	**-**	**-**	**-7.57**	**-100.0%**
Project and Program Evaluation (PPE)[2]	7.57	-	-	-7.57	-100.0%
STEM Professional Workforce	**250.77**	**-**	**244.06**	**-6.71**	**-2.7%**
EHR Core Research (ECR): STEM Professional Workforce Preparation	20.00	-	10.99	-9.01	-45.0%
Cybercorps®: Scholarship for Service (SFS)	55.09	-	55.09	-	-
Graduate Research Fellowship Program (GRFP)	142.58	-	128.45	-14.13	-9.9%
NSF Research Traineeship (NRT)[3]	33.11	-	49.53	16.42	49.6%
Division of Human Resource Development (HRD)	**$162.66**	**-**	**$178.30**	**$15.64**	**9.6%**
Learning and Learning Environments	**58.45**	**-**	**71.74**	**13.29**	**22.7%**
ADVANCE[4]	1.53	-	18.00	16.47	1078.0%
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.54	-0.46	-5.8%
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	34.92	-	33.00	-1.92	-5.5%
Tribal Colleges and Universities Program (TCUP)	14.00	-	13.20	-0.80	-5.7%
Broadening Participation and Institutional Capacity	**74.37**	**-**	**79.93**	**5.56**	**7.5%**
EHR Core Research (ECR): Broadening Participation and Institutional Capacity in STEM	12.88	-	8.93	-3.95	-30.7%
IUSE: Hispanic Serving Institutions (HSI) Program[5]	10.00	-	5.00	-5.00	-50.0%
Big Idea: NSF INCLUDES[6]	5.47	-	20.00	14.53	265.6%
Louis Stokes Alliances for Minority Participation (LSAMP)	46.02	-	46.00	-0.02	-0.0%
STEM Professional Workforce	**29.84**	**-**	**26.63**	**-3.21**	**-10.8%**
Centers for Research Excellence in Science and Technology (CREST)	24.01	-	22.63	-1.38	-5.7%
Excellence Awards in Science and Engineering (EASE)	5.74	-	4.00	-1.74	-30.3%
Integrated NSF Support Promoting Interdisciplinary Res. & Education (INSPIRE)	0.09	-	-	-0.09	-100.0%

NATIONAL SCIENCE FOUNDATION
EDUCATION AND HUMAN RESOURCES FUNDING BY DIVISION AND PROGRAM
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
Division of Undergraduate Education (DUE)	**$254.65**	**-**	**$219.39**	**-$35.26**	**-13.8%**
Learning and Learning Environments	**123.89**	**-**	**97.39**	**-26.50**	**-21.4%**
EHR Core Research (ECR): STEM Learning Environments	13.10	-	9.09	-4.01	-30.6%
Improving Undergraduate STEM Education (IUSE)	90.97	-	78.30	-12.67	-13.9%
IUSE: Hispanic Serving Institutions (HSI) Program[5]	19.82	-	10.00	-9.82	-49.6%
STEM Professional Workforce	**130.75**	**-**	**122.00**	**-8.75**	**-6.7%**
Advanced Technological Education (ATE)	66.05	-	75.00	8.95	13.6%
NSF Innovation Corps (I-Corps™)	0.20	-	-	-0.20	-100.0%
Robert Noyce Teacher Scholarship Program (Noyce)	64.50	-	47.00	-17.50	-27.1%
Total, EHR	**$903.87**	**-**	**$823.47**	**-$80.40**	**-8.9%**
Total, Learning and Learning Environments	**$215.54**	**-**	**$196.91**	**-$18.63**	**-8.6%**
Total, Broadening Participation and Institutional Capacity	**$225.09**	**-**	**$233.87**	**$8.78**	**3.9%**
Total, STEM Professional Workforce	**$463.23**	**-**	**$392.69**	**-$70.54**	**-15.2%**

[1] In FY 2018, CSforAll was supported as a component of STEM+C. The FY 2018 Actual is shown for comparison purposes only. In FY 2020, funding for STEM+C moves to implement CSforAll as a freestanding program and to expand EHR's computer science education portfolio through existing programs.

[2] In FY 2020, PPE funding is zero as EHR evaluates the PPE portfolio. The primary solicitation for PPE, Promoting Research and Innovation in Methodologies for Evaluation (PRIME), will remain on hiatus in FY 2020.

[3] Total FY 2018 Actual funding for NRT is $53.85 million with $20.74 million contributed from the R&RA account. In FY 2020, all funding for NRT resides in the EHR account. For more information on NRT, see the Major STEM Graduate Education narrative in the NSF-wide Investments chapter.

[4] Total FY 2018 Actual funding for ADVANCE is $18.0 million with $16.47 million contributed from the R&RA account. In FY 2020, all funding for ADVANCE resides in the EHR account.

[5] In FY 2017, the HSI Program was funded at $15.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($15.03 million). EHR is responsible for the management of this program.

[6] Total FY 2018 Actual funding for NSF INCLUDES is $17.95 million with $12.48 million contributed from the R&RA account. In FY 2020, all funding for NSF INCLUDES resides in the EHR account. For more information, see the NSF INCLUDES narrative in the NSF-wide Investments chapter.

NATIONAL SCIENCE FOUNDATION
CoSTEM INVENTORY AND POSTDOCTORAL FELLOWSHIP PROGRAMS
BY LEVEL OF EDUCATION
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

		FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actuals: Amount	Percent
Minority-Serving Institutions		**$48.92**	**-**	**$46.20**	**-$2.72**	**-5.6%**
UG	Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	34.92	-	33.00	-1.92	-5.5%
UG	Tribal Colleges and Universities Program (TCUP)	14.00	-	13.20	-0.80	-5.7%
Fellowships and Scholarships		**$614.68**	**-**	**$498.52**	**-$116.16**	**-18.9%**
UG	NSF Scholarships in STEM (S-STEM) (H-1B)	156.39	-	90.00	-66.39	-42.5%
UG	Robert Noyce Scholarship (Noyce) Program	64.50	-	47.00	-17.50	-27.1%
G	Cybercorps®: Scholarship for Service (SFS)	55.09	-	55.09	-	-
G	Graduate Research Fellowship Program (GRFP)	284.85	-	256.90	-27.95	-9.8%
G	NSF Research Traineeship (NRT)	53.85	-	49.53	-4.32	-8.0%
Other Grant Programs		**$652.79**	**-**	**$568.53**	**-$84.26**	**-12.9%**
K-12	Computer Science for All (CSforAll)[1]	*[20.00]*	-	20.00	-	-
K-12	Discovery Research PreK-12 (DRK-12)	88.59	-	95.00	6.41	7.2%
K-12	Innovative Technology Experiences for Teachers and Students (ITEST) (H1-B)	35.87	-	30.00	-5.87	-16.4%
K-12	STEM + Computing (STEM+C) Partnerships[1]	64.37	-	-	-64.37	-100.0%
UG	Advanced Technological Education (ATE)	66.05	-	75.00	8.95	13.6%
UG	Emerging Frontiers in Research and Innovation (EFRI) Research Experience and Mentoring (REM)	1.10	-	0.75	-0.35	-31.8%
UG	Harnessing the Data Revolution (HDR): Data Science Corps (DSC)	-	-	3.00	3.00	N/A
UG	Hispanic Serving Institutions Program (HSI Program)[2]	44.85	-	15.00	-29.85	-66.6%
UG	Improving Undergraduate STEM Education (IUSE)	99.12	-	93.13	-5.99	-6.0%
UG	International Research Experiences for Students (IRES)	11.47	-	13.00	1.53	13.4%
UG	Louis Stokes Alliances for Minority Participation (LSAMP)	46.02	-	46.00	-0.02	-0.0%
UG	Research Experiences for Undergraduates (REU) - Sites and Supplements	87.49	-	76.37	-11.12	-12.7%
UG	Research Experiences for Teachers (RET) in Engineering and Computer Science	7.73	-	5.80	-1.93	-25.0%
G	Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.54	-0.46	-5.8%
G	Training-based Workforce Development for Advanced Cyberinfrastructure (CyberTraining)	6.31	-	5.00	-1.31	-20.7%
O&I	Advancing Informal STEM Learning (AISL)	62.13	-	58.94	-3.19	-5.1%
O&I	Excellence Awards in Science and Engineering (EASE)	5.74	-	4.00	-1.74	-30.3%
O&I	Big Idea: NSF INCLUDES	17.95	-	20.00	2.05	11.4%
Subtotal, Above Categories (CoSTEM Inventory)		**$1,316.39**	**-**	**$1,113.25**	**-$203.14**	**-15.4%**
G	**NSF Postdoctoral Programs**	**$21.94**	**-**	**$19.97**	**-$1.97**	**-9.0%**
	Astronomy and Astrophysics Postdoctoral Fellowships (AAPF)	2.30	-	2.50	0.20	8.7%
	Geosciences Postdoctoral Fellowships	2.42	-	3.07	0.65	26.8%
	Mathematical Sciences Postdoctoral Research Fellowships (MSPRF)	6.00	-	5.40	-0.60	-10.0%
	Postdoctoral Research Fellowships in Biology (PRFB)	8.21	-	6.00	-2.21	-26.9%
	SPRF-Broadening Participation	1.47	-	1.50	0.03	1.8%
	SPRF-Fundamental Research	1.53	-	1.50	-0.03	-2.2%

NATIONAL SCIENCE FOUNDATION
CoSTEM INVENTORY AND POSTDOCTORAL FELLOWSHIP PROGRAMS
BY LEVEL OF EDUCATION
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actuals Amount	Percent
K-12 STEM Education Programs (K-12) Subtotal	**$188.83**	**-**	**$145.00**	**-$43.83**	**-23.2%**
Undergraduate STEM Education Programs (UG) Subtotal	**$633.64**	**-**	**$511.25**	**-$122.39**	**-19.3%**
Graduate and Professional STEM Education Programs (G) Subtotal	**$430.04**	**-**	**$394.03**	**-$36.01**	**-8.4%**
Outreach and Informal STEM Education Programs (O&I) Subtotal	**$85.82**	**-**	**$82.94**	**-$2.88**	**-3.4%**
Total, NSF STEM Education	**$1,338.33**	**-**	**$1,133.22**	**-$205.11**	**-15.3%**

[1] In FY 2018, $10.0 million in EHR funding for CSforAll was supported as a component of STEM+C and $10.0 million in R&RA funding was provided by CISE. The total FY 2018 Actual is shown for comparison purposes only. In FY 2020, CISE continues its investment in CSforAll. Within EHR in FY 2020, funding for STEM+C moves to implement CSforAll as a freestanding program and to expand EHR's computer science education portfolio through the DRK-12 and AISL programs.

[2] In FY 2017, the HSI Program was funded at $15.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($15.03 million). EHR is responsible for the management of this program.

NATIONAL SCIENCE FOUNDATION
RESEARCH INFRASTRUCTURE (RI) FUNDING, BY ACCOUNT AND ACTIVITY
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	FY 2018 Actual	FY 2018 Actual RI Funding	FY 2019 (TBD)	FY 2019 (TBD) RI Funding	FY 2020 Request	FY 2020 Request RI Funding	FY 2020 Request RI change over FY 2018 Actual RI Amount	Percent
BIO	$756.60	$131.03	-	-	$683.36	$118.10	-$12.93	-9.9%
CISE	960.80	155.26	-	-	883.04	154.10	-1.16	-0.7%
ENG	977.90	37.35	-	-	881.42	23.58	-13.77	-36.9%
GEO	907.80	407.26	-	-	787.05	341.13	-66.13	-16.2%
MPS	1,503.41	464.18	-	-	1,255.82	350.29	-113.89	-24.5%
SBE	250.69	64.60	-	-	230.08	56.23	-8.37	-13.0%
OISE	48.98	0.10	-	-	46.24	-	-0.10	-100.0%
OPP	501.72	380.54	-	-	403.39	322.48	-58.06	-15.3%
IA	471.05	103.86	-	-	491.04	98.07	-5.79	-5.6%
U.S. Arctic Research Commission	1.43	-	-	-	1.52	-	-	N/A
Research & Related Activities	$6,380.38	$1,744.17	-	-	$5,662.96	$1,463.98	-$280.19	-16.1%
Education & Human Resources	$903.87	-	-	-	$823.47	-	-	N/A
Major Research Equipment & Facilities Construction	$186.30	$185.73	-	-	$223.23	$222.23	$36.50	19.6%
Agency Operations & Award Management	$328.51	-	-	-	$336.89	-	-	N/A
National Science Board	$4.30	-	-	-	$4.10	-	-	N/A
Office of Inspector General	$15.09	-	-	-	$15.35	-	-	N/A
Total, National Science Foundation	**$7,818.43**	**$1,929.91**	**-**	**-**	**$7,066.00**	**$1,686.21**	**-$243.70**	**-12.6%**

NATIONAL SCIENCE FOUNDATION
RESEARCH INFRASTRUCTURE SUMMARY
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
Operations and Maintenance of Major Facilities[1]	**$1,039.77**	**-**	**$861.94**	**-$177.83**	**-17.1%**
Major Research Facilities Construction Investments	**$228.47**	**-**	**$181.63**	**-$46.84**	**-20.5%**
Construction, Acquisition, and Commissioning (MREFC)[2]	185.73	-	177.23	-8.50	-4.6%
Design Stage Activities[3]	42.74	-	4.40	-38.34	-89.7%
Mid-scale Research Infrastructure[4]	**$57.11**	**-**	**$111.87**	**$54.76**	**95.9%**
MREFC Mid-scale Research Infrastructure	-	-	45.00	45.00	N/A
NSF-wide Mid-scale Research Infrastructure (R&RA)	-	-	30.00	30.00	N/A
Directorate Midscale Research Infrastructure Programs	57.11	-	36.87	-20.24	-35.4%
Major Research Instrumentation (MRI)	**$100.44**	**-**	**$65.00**	**-$35.44**	**-35.3%**
Polar Logistical and Infrastructure Support[5]	**$124.23**	**-**	**$120.61**	**-$3.62**	**-2.9%**
CISE Networking and Computational Resources Infrastructure and Services (NCRIS)[6]	**$118.39**	**-**	**$113.50**	**-$4.89**	**-4.1%**
Research Resources[7]	**$186.47**	**-**	**$157.88**	**-$28.59**	**-15.3%**
BIO	58.78	-	54.15	-4.63	-7.9%
CISE	36.27	-	36.00	-0.27	-0.7%
GEO	57.99	-	47.30	-10.69	-18.4%
MPS	15.65	-	8.02	-7.63	-48.8%
SBE	11.48	-	8.18	-3.30	-28.8%
OPP	6.29	-	4.23	-2.06	-32.7%
Other Research Infrastructure	**$76.32**	**-**	**$75.45**	**-$0.87**	**-1.1%**
Subtotal, Research Infrastructure Support	**$1,931.19**	**-**	**$1,687.88**	**-$243.31**	**-12.6%**
Research Infrastructure Stewardship Offset	-1.29	-	-1.67	-0.38	29.7%
RESEARCH INFRASTRUCTURE TOTAL	**$1,929.91**	**-**	**$1,686.21**	**-$243.70**	**-12.6%**

[1] For facility level detail on operations and maintenance, see the Major Multi-User Research Facilities table in the Facilities chapter.

[2] Construction, Acquisition, and Commissioning are for implementation support provided through the MREFC account. MREFC funding is included for DKIST ($20.0 million in FY 2018); for RCRV ($88.0 million in FY 2018); and LSST ($57.80 million in FY 2018 and $46.34 million in FY 2020); in FY 2020 for: Antarctic Infrastructure Modernization for Science (AIMS) ($97.89 million), High-Lumosity Large Hadron Collider Upgrade (HL-LHC) ($33.0 million), and Mid-scale Research Infrastructure ($45.0 million, shown on the MREFC Mid-scale RI line below).

[3] Design Stage Activities include support for potential next generation multi-user facilities funded through R&RA. This line reflects funding for AIMS in FY 2018 ($16.14 million); for a potential HL-LHC in FY 2018 ($16.60 million, of which $7.50 million funds FY 2019 and FY 2020 activities); for LIGO A+ ($10.0 million in FY 2018 and $400,000 in FY 2020); and for the potential Leadership Class Computing Facility in FY 2020 ($4.0 million).

[4] NSF-wide Mid-scale Research Infrastructure is provided through both the Research and Related Activities account (if the total project cost is less than $20.0 million) and the Major Research Equipment and Facilities account (if the total project cost is greater than $20.0 million). For more information, please refer to the Mid-scale Research Infrastructure narrative in the NSF-wide Investments chapter.

[5] Polar Logistical and Infrastructure Support includes funding for Arctic Logistics; U.S. Antarctic Logistical Support Activities (USALS); and Polar Environment, Health, and Safety (PEHS).

[6] Funding for Networking and Computational Resources Infrastructure excludes support for the potential Leadership Class Computing Facility in FY 2020 ($4.0 million), which is captured under Design Stage Activities above.

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

NSF AUTHORIZATIONS

NATIONAL SCIENCE FOUNDATION CURRENT AUTHORIZATIONS

(Dollars in Millions)

LEGISLATION	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Authorization Levels FY 2018	FY 2019	FY 2020
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)				*(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]	**$182.39**	**-**	**$166.71**	*3.2% of research funds in 2018, 2019 and 2020*		
Small Business Technology Transfer (STTR) Program[2]	**$22.59**	**-**	**$23.44**	*0.45% of research funds in 2018, 2019 and 2020*		
The Research Excellence and Advancements for Dyslexia Act (READ Act), P.L. 114-124[3]	**$10.08**	*****	*****	*$5.00*	*$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]						

NATIONAL SCIENCE FOUNDATION CURRENT AUTHORIZATIONS

(Dollars in Millions)

LEGISLATION	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Authorization Levels FY 2018	FY 2019	FY 2020
Promoting Women in Entrepreneurship Act, P.L. 115-6 (Does not authorize appropriations) *Amends the Science and Engineering Equal Opportunities Act to authorize the National Science Foundation to encourage its entrepreneurial programs to recruit and support women to extend their focus beyond the laboratory and into the commercial world.*				*(Does not authorize appropriations)*		
National Defense Authorization Act for Fiscal Year 2018, P.L. 115-91 (Does not authorize appropriations) *Amends the Cyber Scholarship-for-Service program established under section 302 of the Cybersecurity Enhancement Act of 2014 (15 U.S.C. 7442) to implement a pilot program at community colleges to provide scholarships to eligible students who are pursuing associate degrees or specialized program certifications in the field of cybersecurity; and have bachelor's degrees; or are veterans of the Armed Forces.* *It also amends the National Science Foundation Authorization Act of 2002 (42 U.S.C. 1862n-1(i)) to define the term 'mathematics and science teacher 'and the term 'science, technology, engineering, or mathematics professional'.*				*(Does not authorize appropriations)*		
Women in Aerospace Education Act, P.L. 115-303 (Does not authorize appropriations) *Amends the National Science Foundation Authorization Act of 2002 to permit certain grants awarded by the National Science Foundation (NSF) to be used to provide internships that include research experiences at national laboratories and National Aeronautics and Space Administration (NASA) centers. NSF Master Teaching Fellows and undergraduate freshman and sophomore students studying to become mathematics and science teachers under the Robert Noyce Teacher Scholarship Program are eligible for the internships.*				*(Does not authorize appropriations)*		

NATIONAL SCIENCE FOUNDATION CURRENT AUTHORIZATIONS

(Dollars in Millions)

LEGISLATION	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Authorization Levels FY 2018	FY 2019	FY 2020
National Earthquake Hazards Reduction Program Reauthorization Act of 2018, P.L. 115-307 *Amends the Earthquake Hazards Reduction Act of 1977 to expand activities under the National Earthquake Hazards Reduction Program to include: (1) gathering information on community resilience (i.e., the ability of a community to prepare for, recover from, and adapt to earthquakes); (2) publishing a systematic set of maps of active faults and folds, liquefaction susceptibility, susceptibility for earthquake-induced landslides, and other seismically induced hazards; and (3) continuing the development of the Advanced National Seismic System, including earthquake early warning capabilities.* *With respect to earthquake hazard reduction activities, the bill revises or expands the duties of: (1) the Interagency Coordinating Committee on Earthquake Hazards Reduction, (2) the National Institute of Standards and Technology (NIST), (3) the Federal Emergency Management Agency (FEMA), (4) the U.S. Geological Survey (USGS), and (5) the National Science Foundation.* [5]	**$65.00**	**-**	**$54.00**		*$54.00*	*$54.00*
National Quantum Initiative Act, P.L. 115-368 *Authorizes the National Science Foundation to carry out a basic research and education program on quantum information science and engineering, and award grants for the establishment of at least 2 but not more than 5 Multidisciplinary Centers for Quantum Research and Education up to $10 million each for each of fiscal years 2019 through 2023.*				*(Does not authorize appropriations)*		

[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 2018 Actuals funding includes $5.01 million for dyslexia research.

[5] Authorizes $54.0 million for the National Earthquake Hazards Reduction Program at NSF for each of fiscal years FY 2019 through FY 2023.

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)

Summary

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 or a non-profit research organization."

Background

NSF launched the Computer Science for All: Researcher Practitioner Partnerships (CS for All: RPP) program in 2017 with solicitation NSF 17-525[1]. In 2018, NSF issued an updated solicitation, NSF 18-537[2].

[1] www.nsf.gov/pubs/2017/nsf17525/nsf17525.htm
[2] www.nsf.gov/pubs/2018/nsf18537/nsf18537.htm

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 preK-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 and 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; preK-8 teachers with the instructional materials and preparation they need to integrate CS and CT into their teaching; and schools and districts the resources needed to define and evaluate multi-grade pathways in CS and CT."

The revised solicitation added the focus on researcher-practitioner partnerships that are supporting schools and districts in defining and evaluating multi-grade pathways in CS and CT. Articulation of coursework and experiences in CS and CT from elementary to middle school, middle to high school, and high school into the first years of college is important to support systemic implementation of CS and CT in schools.

Metrics

Short-, mid-, and longer-term metrics for success were developed and reported upon, as follows:

- 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 (beyond 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 NSF's Directorate for Education and Human Resources and the Evaluation and Assessment Capability group within NSF's 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 using these longer-term metrics.

<u>Report on the Success of the Program as Measured by the Short-Term Metrics</u>

Between the submission of the last annual report and December 2018, 35 new awards were made by the program: Below is a summary of the CSforAll: RPP projects funded in FY 2018 pursuant to NSF 18-537:

- 14 awards address subsection (b)(2) A and (b)(2) B;
- 11 awards address subsection (b)(2) C; and
- 10 awards address multi-grade pathways to CT and CS

Finally, all new awards identified at least one underrepresented or underserved group, as outlined in the table below, to address subsection (b)(2) D. (Note: some awards serve more than one underrepresented group and thus the numbers of awards in the table total more than 35).

Underrepresented or Underserved Group Served by Backbone Organizations

Category	Groups Served
Rural	23
Low Socio-Economic Status	12
Disabilities	3
Pacific Islanders	3
Women/Girls	11
English Language Learners	4
African-Americans	22
Native Americans	7
Latino/a	19

NATIONAL SCIENCE FOUNDATION (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 2018

This report summarizes fiscal year (FY) 2018 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; and
(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 cyberinfrastructure development; (2) Co-Funding in partnership with 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)).c

EPSCoR's strategies and objectives in FY 2018 remain the same as those described in the FY 2017 report. Specifically, the mission of EPSCoR is "to enhance research competitiveness of targeted jurisdictions (states, territories, commonwealths) by strengthening STEM capacity and capability." 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, NSF focus 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 jurisdiction, under EPSCoR (Sec. 103(d)(2)(A)).

In FY 2018, NSF EPSCoR invested a total of $170.59 million in support of its programmatic activities. Of this, $142.21 million (83.4 percent) was directed to RII, $27.59 million (16.2 percent) to co-funding, and $790,000 (0.4 percent) to outreach activities and workshops. The table below details the investments from EPSCoR resources and EPSCoR investments in co-funding actions.

FY 2018 EPSCoR Funding by Jurisdiction

(Dollars in Millions)

EPSCoR Jurisdiction	RII Program	Outreach & Workshops	EPSCoR Co-funding	EPSCoR Total
AK	$4.36	-	$0.68	$5.04
AL	11.05	-	3.27	14.32
AR	10.72	-	1.42	12.14
DE	4.91	-	1.30	6.21
GU	-	-	-	-
HI	5.37	-	0.42	5.79
ID	6.10	-	1.21	7.31
KS	10.73	-	0.84	11.57
KY	7.22	-	0.56	7.78
LA	4.86	-	0.75	5.61
ME	7.25	-	0.59	7.84
MS	5.36	-	0.38	5.74
MT	4.23	-	1.27	5.50
ND	5.61	-	1.16	6.77
NE	3.13	-	1.08	4.21
NH	6.71	-	1.18	7.89
NM	4.13	-	0.92	5.05
NV	0.19	-	1.01	1.20
OK	0.12	-	1.12	1.24
PR	1.00	-	0.85	1.85
RI	4.18	-	0.19	4.37
SC	4.57	0.74	2.37	7.68
SD	4.66	-	1.33	5.99
VI	4.17	-	-	4.17
VT	10.43	-	0.28	10.71
WV	4.00	-	2.46	6.46
WY	4.75	-	0.56	5.31
Admin	2.40	0.05	0.39	2.84
Total	**$142.21**	**$0.79**	**$27.59**	**$170.59**

Total NSF Funding Made Available in all EPSCoR Jurisdictions (Sec. 103 (d)(2)(B)).

In FY 2018, NSF invested a total of $825.80 million in support of EPSCoR jurisdictions. The table below details NSF investments in EPSCoR jurisdictions including research support funding, education and human resources, and major research equipment.

FY 2018 NSF Funding
Made Available to All EPSCoR Jurisdictions
(Dollars in Millions)

EPSCoR Jurisdiction	NSF Funding
AK	$45.03
AL	60.14
AR	28.98
DE	36.65
GU	-
HI	45.31
ID	24.75
KS	41.17
KY	32.89
LA	42.51
ME	33.44
MS	21.79
MT	30.57
ND	16.05
NE	34.17
NH	38.75
NM	46.03
NV	22.09
OK	24.62
PR	19.49
RI	43.61
SC	64.02
SD	15.02
VI	6.30
VT	19.39
WV	15.96
WY	17.07
Total	**$825.80**

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 promote the coordination and integration of recipient jurisdictions into major NSF programmatic activities. Additionally, EPSCoR consults and engages NSF disciplinary program officers (POs) in merit review processes 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 projects 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 observers, 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 grantee 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 the 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 on NSF strategic priorities and funding opportunities.

In FY 2018, EPSCoR staff promoted engagement of the EPSCoR community in NSF and other national activities. Examples are:

- Hosted its annual principal investigator meeting, a two-day event with opportunities for the EPSCoR community and NSF program officers to interact and share best practices in strategic planning, diversity, communication, evaluation, and other areas of importance to EPSCoR jurisdictions and NSF.
- Hosted a half-day session with the EPSCoR Interagency Coordinating Committee at the 7th Biennial National IDeA Symposium of Biomedical Research Excellence in Washington, D.C. This event helped to capitalize on federal agency investments in EPSCoR and EPSCoR-like programs and provided opportunities for interactions and possible new collaborations between grantees.
- Encouraged EPSCoR-supported faculty to participate in NSF committee and review panels across NSF (e.g., COVs, site visits, and merit review panels).
- Continued the 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. In addition, these awards have a particular focus on the development of early career/junior faculty. In FY 2018, proposals were invited on the topic of understanding the relationship between genome and phenome, aligned with the NSF Big Idea of Understanding the Rules of Life, and nine awards were made.
- Continued the RII Track-4, EPSCoR Research Fellows solicitation, which provides opportunities for early career researchers to further develop their individual research potential through extended collaborative visits to the Nation's premier private, governmental, or academic research centers. Proposals in all areas of science and engineering supported by NSF were invited and 40 awards were made.

EPSCoR Reviewers (Sec. 103(d)(2)(D)).

Demographics of all reviewers who evaluated EPSCoR proposals or the program in FY 2018 are as follows: of the 138 reviewers, 25 percent were underrepresented minorities, 38 percent were female, 11 percent were from EPSCoR jurisdictions, 65 percent were new reviewers for EPSCoR, and eight 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 2018, there were 772 institutional collaborations within EPSCoR jurisdictions; 633 institutional collaborations between EPSCoR jurisdictions and other EPSCoR and non-EPSCoR jurisdictions; and 209 collaborations between institutions in EPSCoR jurisdictions and in foreign countries. These collaborative efforts highlight the vast network of institutional involvement among EPSCoR jurisdictions and their partners in RII projects.

Among the 143 awards co-funded by EPSCoR in FY 2018, 82 involved collaborative research between multiple institutions. Of those 82 collaborative awards, 56 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)).

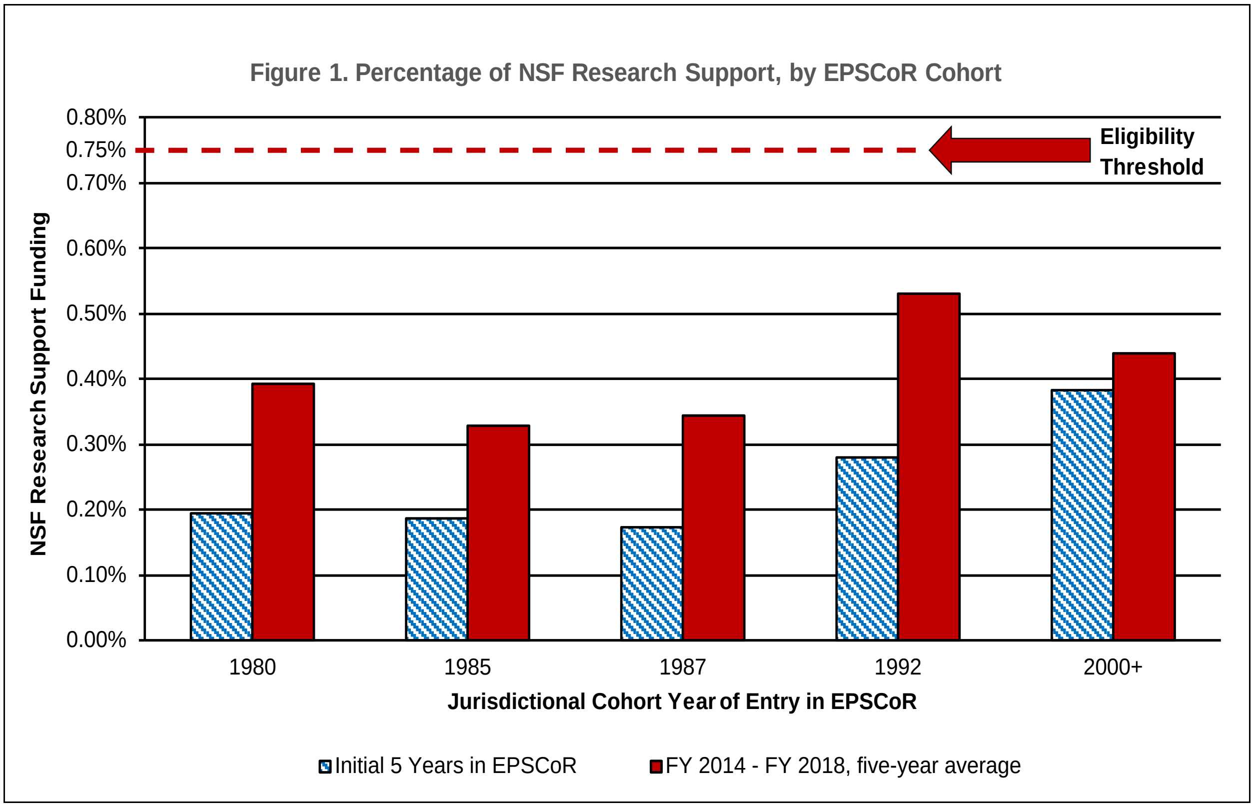
Eligibility to participate in NSF EPSCoR programmatic activities is based upon the jurisdictions' demonstrated ability to obtain NSF research funds. Currently, a jurisdiction is eligible to participate in EPSCoR programs if its level of NSF research support is equal to or less than 0.75 percent of the total NSF research and related activities budget 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. As in FY 2017, Iowa, Missouri, Tennessee, and Utah exceeded the 0.75 percent threshold and these jurisdictions continued to be ineligible to compete in new FY 2018 RII competitions. In FY 2018, New Mexico also rose above the 0.75 percent eligibility threshold for the first time and became ineligible for RII competitions. New Mexico will continue to receive EPSCoR co-funding and outreach for an additional three years; Iowa, Missouri, Tennessee, and Utah have been ineligible for more than three years, so no longer receive any EPSCoR funding.

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 and are still EPSCoR-eligible for RII competitions: Alaska, Delaware, Guam, Hawaii, New Hampshire, Rhode Island, and the U.S. Virgin Islands. Former EPSCoR jurisdictions Iowa, Missouri, New Mexico, Tennessee, and Utah are excluded because they were no longer EPSCoR-eligible in FY 2018.

Each cohort shows an increase in competitiveness over the periods of participation. For example, the 1980 cohort shows a 101 percent increase in NSF research funding over the past 38 years of EPSCoR activity. The 1985 cohort (Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Puerto Rico, Vermont, and Wyoming) demonstrates a 76 percent increase during its 33 years of participation in EPSCoR. The 1987 cohort (Idaho, Louisiana, Mississippi, and South Dakota) shows a 101 percent increase over the past 31 years, while the 1992 cohort (Kansas and Nebraska) has an 89 percent increase in competitiveness over its 26 years of EPSCoR involvement. Currently eligible 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 15 percent increase in research funding. The data for each jurisdiction is provided in the table immediately after the figure.

Figure 1. Percentage of NSF Research Support Funding by EPSCoR Cohort



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

	Initial 5 Years in EPSCoR	Most Recent 5 Year Period (FY 2014-2018)
1980 Cohort	0.19%	0.39%
Arkansas	0.10%	0.32%
Maine	0.27%	0.33%
Montana	0.13%	0.38%
South Carolina	0.41%	0.71%
West Virginia	0.07%	0.23%
1985 Cohort	0.19%	0.33%
Alabama	0.33%	0.53%
Kentucky	0.22%	0.46%
Nevada	0.14%	0.31%
North Dakota	0.06%	0.19%
Oklahoma	0.30%	0.51%
Puerto Rico	0.15%	0.17%
Vermont	0.10%	0.21%
Wyoming	0.20%	0.25%
1987 Cohort	0.17%	0.35%
Idaho	0.08%	0.31%
Louisiana	0.36%	0.57%
Mississippi	0.16%	0.28%
South Dakota	0.09%	0.22%
1992 Cohort	0.28%	0.53%
Kansas	0.34%	0.58%
Nebraska	0.22%	0.48%
2000+ Cohort	0.38%	0.44%
Alaska	0.55%	0.54%
Delaware	0.41%	0.54%
Guam	0.02%	0.02%
Hawaii	0.56%	0.56%
New Hampshire	0.44%	0.61%
Rhode Island	0.70%	0.73%
Virgin Islands	-	0.08%

The following table demonstrates the quantifiable outputs of NSF EPSCoR's RII Track-1 program over the last five 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 encompass 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=27*)

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Total
Primary Support Publications	591	581	409	293	404	**2,278**
Partial Support Publications	1,001	1,026	927	692	640	**4,286**
Grants Awarded	601	563	675	455	505	**2,799**
Value of Grants Awarded (Dollars in Millions)	$278.80	$181.80	$379.10	$492.10	$269.13	**$1,600.93**
Patents Awarded	15	13	14	17	8	**67**
Patents pending	38	44	34	29	15	**160**

*The maximum number of jurisdictions with active RII Track-1 awards in FY 2018. 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 five fiscal years in the RII Track-1 program. The number of faculty and students involved in RII Track-1 projects has 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

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Total
Faculty Supported	1,581	1,602	1,552	1,183	1,126	**N/A***
Post-Docs Supported	215	231	200	156	179	**N/A***
Graduate Students Supported	1,346	1,361	1,332	1,056	1,128	**N/A***
Undergraduates Supported	1,867	1,965	1,861	1,220	1,187	**N/A***
New Faculty Hired	73	89	84	54	27	**327**
Graduate Degrees Conferred	326	245	258	254	262	**1,345**
Undergraduate Degrees Conferred	380	408	404	634	357	**2,183**

* 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.

NSF EPSCoR is continuing to refine and implement a cohesive Research Competitiveness evaluation framework for the program. This evaluation, once completed in 2020, will address the legislative objective of increasing the research competitiveness of jurisdictions receiving EPSCoR funding by (1) developing a flexible framework to explore, define, and measure research competitiveness in relation to each unique jurisdictional context, and (2) using evidence of jurisdictional progress toward research competitiveness over time for strategic program improvement. The evaluation builds on the findings and recommendations from the EPSCoR retrospective evaluation completed by the Science and Technology Policy Institute (STPI) in 2012. This new, forward looking contract has been underway since 2017. Key activities to date include identification and merging of data sets, cleaning of data sets, preliminary descriptive and correlational analyses, and refinement of the logic model for the research competitiveness framework.

RESEARCH AND RELATED ACTIVITIES (R&RA) $5,662,960,000

-$717,420,000 / -11.2%

The FY 2020 Budget Request for the Research and Related Activities account is $5,662.96 million. Funding within the R&RA Appropriation invests in early-stage research as well as development of a future-focused science and engineering workforce that can support the private sector and accelerate progress in basic science and engineering research.

NSF is the only federal agency dedicated to funding basic research across all areas of science and engineering. In FY 2020, NSF will continue its longstanding commitment to investing in learning and discovery that will promote the innovations that will help build the foundation for the Nation's future prosperity.

R&RA Funding

(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Biological Sciences	$756.60	-	-	$683.36	-$73.24	-9.7%
Computer & Information Science and Engineering	960.80	-	-	883.04	-77.76	-8.1%
Engineering	977.90	-	-	881.42	-96.48	-9.9%
Geosciences	907.80	-	-	787.05	-120.75	-13.3%
Mathematical & Physical Sciences	1,503.41	-	-	1,255.82	-247.59	-16.5%
Social, Behavioral & Economic Sciences	250.69	-	-	230.08	-20.61	-8.2%
Office of International Science and Engineering	48.98	-	-	46.24	-2.74	-5.6%
Office of Polar Programs	501.72	-	-	403.39	-98.33	-19.6%
Integrative Activities	471.05	-	-	491.04	19.99	4.2%
U.S. Arctic Research Commission	1.43	-	-	1.52	0.09	6.3%
Total, R&RA	**$6,380.38**	**$6,334.48**	**$6,520.00**	**$5,662.96**	**-$717.42**	**-11.2%**

[1] Annualized CR amount shown to be consistent with figures presented in the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

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; ~~$6,150,680,000,~~ $5,662,960,000, to remain available until September 30, ~~2020,~~ 2021, of which not to exceed ~~$600,000,000~~ $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.

Research and Related Activities
FY 2020 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 2018 Appropriation	$6,350.78	$33.89	-$24.49	$20.20	-	$6,380.38
FY 2019 Annualized CR	6,334.48	24.49				6,358.97
FY 2019 Enacted	6,520.00					6,520.00
FY 2020 Request	5,662.96					5,662.96
$ Change from FY 2019 Enacted						-$857.04
% Change from FY 2019 Enacted						-13.1%

Totals exclude reimbursable amounts.

Explanation of Carryover

Within the Research and Related Activities (R&RA) account, $28.87 million (including $4.38 million in reimbursable funds) was carried over into FY 2019.

Directorate for Engineering
- Amount: $2.38 million
- Reason: SBIR Phase II to be used on SBIR Phase I or Phase II awards depending on when funds become available. The carryover amount is due to (1) the program receiving a significantly larger allocation than anticipated when early FY 2018 decisions were being made, and (2) the conversion of SBIR/STTR operations costs to “outside the target costs.” This mid-year change increased available SBIR/STTR award funding by an additional $5.0 million.
- Obligation: FY 2019 Quarter 2

Directorate for Mathematical and Physical Sciences (R&RA No-Year funding)
- Amount: $12.30 million
- Reason: Arecibo Observatory Hurricane Maria Relief Funding.
- Obligation: Anticipated FY 2019 Quarter 3 (The proposal for Hurricane Maria repairs will be submitted to AST in mid-March. Funds are expected to be fully obligated in FY 2019.)

Integrative Activities
- Amount: $542,310
- Reason: Funds to support Proposal Management Efficiencies contracts that were not ready for obligation in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Integrative Activities for Convergence Accelerator
- Amount: $3.94 million
- Reason: These carryover funds will be used to fund start-up activities for the new Convergence Accelerators for Harnessing the Data Revolution for 21st-Century Science and Engineering ($1.97 million) and for the Future of Work at the Human-Technology Frontier ($1.97 million).
- Obligation: Anticipated FY 2019 Quarter 4

Integrative Activities for Program Planning and Policy Development

- Amount: $500,000
- Reason: These carryover funds will be used to co-fund a Growing Convergence Research proposal from the GCR prospectus/proposal cycle beginning in October 2018. (Funds were initially reserved to co-fund an invited GCR RAISE proposal from the FY 2018 cycle, but that proposal was subsequently recommended for declination by the review panel.)
- Obligation: Anticipated FY 2019 Quarter 4

National Coordination Office for Networking and Information Technology Research and Development

- Amount: $316,840
- Reason: Operational funds are needed to continue government procurements and operations.
- Obligation: Anticipated FY 2019 Quarter 3

National Nanotechnology Coordination Office

- Amount: $126,602
- Reason: NNCO's carryover will be used to fund the required Quadrennial Review of the National Nanotechnology Initiative. In addition, funds carried over will be used to cover rent in NNCO's new location and other operational costs.
- Obligation: Anticipated FY 2019 Quarter 2

The remaining R&RA carryover of $4.39 million consists of funds from throughout the Foundation for selected projects that were not ready for obligation in FY 2018.

DIRECTORATE FOR BIOLOGICAL SCIENCES (BIO) **$683,360,000**
-$73,240,000 / -9.7%

BIO Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Molecular & Cellular Biosciences (MCB)	$143.05	-	$125.75	-$17.30	-12.1%
Integrative Organismal Systems (IOS)	192.17	-	168.93	-23.24	-12.1%
Environmental Biology (DEB)	155.00	-	141.70	-13.30	-8.6%
Biological Infrastructure (DBI)	181.31	-	163.16	-18.15	-10.0%
Emerging Frontiers (EF)	85.06	-	83.82	-1.24	-1.5%
Total	**$756.60**	**-**	**$683.36**	**-$73.24**	**-9.7%**

About BIO

BIO supports fundamental research and infrastructure that advances a unified understanding of life in all forms, from the biological molecules that are the machinery of living cells to the populations of organisms and species that underpin the functioning of the Nation's ecosystems. Advances in biological sciences stimulate new technologies and directions for economic growth, and provide solutions for national needs in food, health, energy, and environment. For example, BIO supported research on how plants and animals respond and adapt to changing environments informs efforts to control invasive spread of non-native species and to predict and prevent the emergence of infectious diseases. Foundational BIO-supported research on microbes and their interactions with plants is fueling a revolution in agriculture. BIO support for basic research in cellular and synthetic biology is spawning advances in bio-based manufacturing and innovations that underpin the bioeconomy.

Fundamental research in BIO is also critical to convergent research in frontier areas of science and technology. Collaborations between the biological and physical sciences have contributed to advances such as biological computing, taking advantage of the extraordinary information density in genetic polymers, and the development of neuro-technologies that are powering advances in neuroscience and cognition. Quantum biology—the application of quantum theory to biological systems—provides tantalizing new insights into the power of photosynthesis as well as a fundamental understanding of vision, olfaction, and magnetoreception. Quantum biology research will enable bioinspired designs based on these quantum energy production and sensing systems that will enhance American security. Biology's need to quantify living systems at all scales have propelled the frontiers of research in statistics, mathematical and computer sciences to consider larger and more complex data sets that benefit from machine learning and artificial intelligence. BIO also enables the development of a skilled workforce capable of foundational research and infrastructure development necessary for the unification of all the biological sciences as well as collaboration with scientists and engineers in other disciplines to speed understanding and innovation.

BIO provides the stewardship and foundational support for URoL, a convergence research funding opportunity focused on addressing scientific and societal needs. As the lead directorate for the URoL Big Idea, BIO is the steward of funds designated to the URoL NSF-wide investment. By framing the essential challenges and opportunities associated with genotype to phenotype (structure to function) relationships, BIO enables research that leads to a predictive understanding of biological systems at all scales. This knowledge is what drives advances in understanding the human body and improving health and will permit sustainable, efficient food production. It will allow the harnessing of biological systems to enable bio-based manufacturing and new forms of energy production.

BIO is making contributions to several other NSF's Big Ideas. BIO participates in the QL—contributing to more efficient and robust quantum technologies for solar energy harvesting, communication, and navigation as well as cutting edge DNA-based quantum computing. BIO will support basic research in this area primarily through established research programs in MCB and research resource programs in DBI. BIO is on the leading edge of HDR—from contributing to the mapping and understanding of the properties, structure, and functions of tens of thousands of molecules in cells, to collecting and analyzing data from leading facilities such as the National Ecological Observatory Network (NEON), which seeks to enhance knowledge of environmental change, land use change, and invasive species on natural resources and biodiversity. BIO investments include CyVerse, Protein Data Bank, iDigBio, and Advancing Digitization of Biodiversity Collections. BIO participates in the NNA Big Idea through investments in environmental research and observational infrastructure in the Arctic, through Long-Term Ecological Research program (LTER) and NEON. For more information about the Big Ideas, please see the narratives in the NSF-Wide Investments chapter.

BIO provides 69 percent of the federal funding for non-medical, basic research at academic institutions in the life sciences.

Major Investments

BIO Major Investments
(Dollars in Millions)

Area of Investment	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Advanced Manufacturing	$3.33	-	$3.33	-	-
Artificial Intelligence (AI)	12.53	-	13.78	1.25	10.0%
CAREER	45.54	-	41.09	-4.45	-9.8%
IUSE	2.23	-	1.90	-0.33	-14.8%
I-Corps™	0.98	-	1.00	0.02	2.0%
Quantum Information Sciences (QIS)	0.50	-	3.28	2.78	556.0%
UtB	45.56	-	43.21	-2.35	-5.2%
BRAIN Initiative	*15.50*	-	*19.54*	*4.04*	*26.1%*
NSF's Big Ideas					
URoL Stewardship	-	-	*30.00*	*30.00*	*N/A*

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

- Advanced Manufacturing: BIO will support Advanced Manufacturing in collaboration with ENG, by supporting advances in standards in synthetic biology, the development of tools that will advance biomanufacturing and support for an Industry-Academia-NSF partnership (the Engineering Biology Research Consortium) that provides leadership and training to a network of practitioners that will enable the development of a thriving bioeconomy.

- AI: BIO, together with other NSF directorates/offices, will increase support for artificial intelligence. BIO's AI investments occur primarily in DBI through the Advances in Biological Informatics program, and center-scale investments that advance computational capacity in bioinformatics. Artificial Intelligence methods such as machine learning, natural language processing, computer vision, and genetic algorithms are increasingly applied in biological research to solve problems such as genome sequence alignment, prediction of protein structure, reconstructing evolutionary relationships, predicting species range distributions, and extracting quantitative information from multi-media data sources.

- IUSE: 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.

- I-Corps™: BIO will increase 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.

- QIS: BIO will increase support for QIS through investments in fundamental research in biophysics that seek to understand quantum phenomena within living systems and can inform applications in quantum information science.

- UtB: BIO will continue to support 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: As part of UtB, BIO will sustain support for the BRAIN Initiative through the Next Generation Networks for Neuroscience (NeuroNex) program, including a new funding opportunity involving a partnership of NSF and funding agencies in Germany, United Kingdom, and Canada.

- URoL: BIO will provide stewardship support for NSF URoL Big Idea initiative. URoL emphasizes multi-disciplinary, team science approaches to achieving a predictive understanding of how complex traits of an organism emerge from the interaction of its genetic makeup with the environment. Science outcomes from URoL will advance biological theory explaining the complexity, diversity, and adaptability of all living systems, inform applications in human health and agriculture, and expand the bioeconomy.

BIO Funding for Centers Programs and Facilities

BIO Funding for Centers Programs

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$21.00**	**-**	**$16.10**	**-$4.90**	**-23.3%**
Centers for Analysis & Synthesis (DBI)	6.00	-	4.80	-1.20	-20.0%
STC: Bio/computation Evolution in Action CONsortium (BEACON) (DBI)	5.00	-	1.30	-3.70	-74.0%
STC: Biology with X-ray Lasers (BioXFEL) (DBI)	5.00	-	5.00	-	-
STC: Center for Cellular Construction (CCC) (DBI)	5.00	-	5.00	-	-

For detailed information about NSF Centers programs, please see the NSF-Wide Investments chapter.

BIO Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$71.90**	**-**	**$63.60**	**-$8.30**	**-11.5%**
National Ecological Observatory Network (NEON)[1]	67.90	-	62.60	-5.30	-7.8%
Cornell Energy Synchrotron Source (CHESS)	4.00	-	1.00	-3.00	-75.0%

[1] FY 2018 Actual total includes a one-time expenditure of $3.0 million for a cyberinfrastructure enhancements, not related to O&M.

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

Funding Profile

BIO Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,767	-	4,800
Number of New Awards	1,192	-	1,110
Funding Rate	25%	N/A	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	4,207	-	4,200
Number of Research Grants	994	-	900
Funding Rate	24%	N/A	21%
Median Annualized Award Size	$196,844	-	$200,000
Average Annualized Award Size	$226,756	-	$220,000
Average Award Duration, in years	3.2	-	3.2

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

In FY 2020, BIO will invest $16.10 million in research centers, accounting for 2.4 percent of the BIO budget. This total is down from FY 2018 Actual as two centers are phasing down as planned. BIO's FY 2020 Request funds one Center for Analysis and Synthesis, the National Socio-Environmental Synthesis Center (SESync), and the three Science and Technology Centers.

O&M funding for BIO-supported facilities is 9.4 percent of BIO's FY 2020 Request.

Program Monitoring and Evaluation

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

- IOS will initiate a National Academies of Sciences, Engineering, and Medicine (the National Academies) workshop on future directions in Functional Genomics, which will inform future IOS investments in this critical area related to NSF's Big Idea, URoL.

- DBI funded an award (1827445) to the National Academies, entitled, "Biological Collections: Their Past, Present, and Future Contributions and Options for Sustaining Them". This will inform how the division chooses to proceed at the end of the 10-year campaign on digitizing and maintaining collections through the Advancing Digitization of Biodiversity Collections and Collections in Support of Biological Research programs.

Workshops and Reports:

- MCB supported multiple workshops that have and continue to inform the planning of the division's research programs.
  - Workshops entitled "Finding your inner modeler: how computational biology can advance your research and how to get started" were initiated in FY 2017. The series of workshops were developed to promote the use of computational modeling by cell biologists. These workshops contribute to the continued enhancement of the quantitative/predictive portfolio of awards in MCB.
  - A workshop entitled "The Role of Crowdfunding in the STEM Ecosystem" was held in early FY 2018. The workshop was convened to examine the practice, benefits, challenges, and limitations of using crowdfunding to finance basic research in the fields of science, technology, engineering, and mathematics. MCB is currently preparing a solicitation that provides seed funding for projects and resources to take advantage of community co-funding as a new model of partnership within MCB.
  - A workshop entitled "Towards the Design of Synthetic Cells" was held in May 2018. The workshop explored the open challenges in the design and assembly of synthetic cells from perspectives spanning the biological and physical sciences, and engineering. The report from this workshop informed the development of the solicitation released in late FY 2018; Understanding the Rules of Life: Building a Synthetic Cell: An Ideas Lab Activity.[1]
  - A workshop entitled "2018 Workshop: Quantum Biology and Quantum Processes in Biology", held in November 2018, brought together leaders in the field of quantum biology from the biological and physical sciences, to explore the opportunities and challenges in quantum biology. The results of this workshop have helped inform BIO's participation in the QL NSF Big Idea, and planning for new activities in the Quantum Biology space.
- IOS supported multiple workshops, meetings and Research Coordination Networks that informed planning of the division's research programs for FY 2020.
  - The FY 2016 NSF-sponsored workshop report "Unpacking the Phenotype, Deciphering Genome to Phenome Relationships: Interdisciplinary Research at the Interface of the Biological and Mathematical Sciences"[2] led to current investments in the recently established Mathematics of Complex Biological Systems (MathBioSys) Research Centers co-funded by NSF and the Simons Foundation.
  - A workshop in October 2017 "Breakthroughs 2030: A Strategy for Food and Agricultural Research" led to a National Academies' Breakthroughs 2030 report that helped guide the FY 2019 solicitation for plant genomics research in IOS.[3]
  - In September 2016, "A Scientific Planning Workshop for Coordinating Brain Research Around the Globe" involved more than 60 scientists from 12 countries and a wide range of disciplines discussed grand challenges for global brain sciences and infrastructure needs. The issues raised during the workshop inform NSF's BRAIN Initiative and UtB activities.
  - The 2016 "Collaborative Workshop in Advancing Research on Plant Biotic Interactions" and its

[1] www.nsf.gov/pubs/2018/nsf18599/nsf18599.htm
[2] www.nsf.gov/mps/dms/documents/Deciphering_Genome-to-Phenome_Relationships.pdf
[3] http://nas-sites.org/dels/studies/agricultural-science-breakthroughs/

resultant white paper[4] continues to provide valuable information on investments for IOS, including the interagency USDA-NSF Plant Biotic Interactions Program.

- The "Interagency Strategic Plan for Microbiome Research FY 2018-2022"[5] released in April 2018 serves as a guide for IOS investment into microbiomes, including microbial interactions with the environment, with animals and plants, and important ecosystem services such as soil stability, fertility, and sustainability.
- A 2016 symposium entitled "Neuroecology: Neural Mechanisms of Sensory and Motor processes that Mediate Ecologically Relevant Behaviors" has been influential in guiding investments into the development of research themes in behavior and neurobiology.

- DEB supported the following workshops to inform the planning of the division's research programs for FY 2020:
  - Two 2018 NSF-National Natural Science Foundation of China (NSFC) workshops on Ecology and Evolution of Infectious Diseases provided valuable insights on future investments for DEB and helped establish a co-funding arrangement between NSF and NSFC within the Ecology and Evolution of Infectious Diseases program.
  - A 2017 workshop "Addressing data management challenges within integrative biodiversity projects" provided valuable information on investments for DEB related to integrating data across spatial, temporal, and biological scales

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

- The IOS COV convened June 2018 and reviewed division operations and the core programmatic portfolio for the four-year period spanning FY 2014 through FY 2017. Included in the COV review was an evaluation of the Plant Genome Research Program operations and program portfolio over a five-year period from FY 2013 through FY 2017. The COV stated that IOS is a scientifically high-impact division centrally important to the overall mission of BIO. The COV was impressed at how well program directors and staff have functioned in promoting the mission of IOS. Major recommendations of the COV were to develop a broader strategic vision aligned with the priorities of the agency and directorate. IOS is addressing recommendations of the COV through its future planning activities, including a series of all-hands planning meetings, science discussions, and retreats.
- The MCB COV convened June 2018 and reviewed division operations and the programmatic portfolio for the four-year period spanning FY 2014 through FY 2017. Overall, the COV considered MCB to be on positive trajectory. The COV commended MCB for the work of the dedicated staff, the rigorous merit review, and the impactful science funded by the division. The COV had recommendations for ensuring that MCB sustained its positive trajectory. These include developing mechanisms to ensure retention and development of staff, to better communicate to the public the impact of MBC investments, to plan strategically for new funding opportunities and review paradigms, and to develop effective outreach to investigators less resilient to rejection. MCB is incorporating these recommendations in its future planning activities.
- In 2019, a COV will review programs in DEB.
- In 2020, a COV will review programs in DBI.

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

[4] https://apsjournals.apsnet.org/doi/10.1094/MPMI-01-17-0010-CR
[5] https://science.energy.gov/~/media/ber/pdf/workshop%20reports/Interagency_Microbiome_Strategic_Plan_FY2018-2022.pdf

People Involved in BIO Activities

Number of People Involved in BIO Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	3,665	-	3,300
Other Professionals	1,350	-	1,200
Postdoctoral Associates	1,435	-	1,300
Graduate Students	2,691	-	2,400
Undergraduate Students	4,623	-	4,200
Total Number of People	**13,764**	**-**	**12,400**

DIVISION OF MOLECULAR AND CELLULAR BIOSCIENCES (MCB) **$125,750,000**
-$17,300,000 / -12.1%

MCB Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$143.05**	**-**	**$125.75**	**-$17.30**	**-12.1%**
Research	**141.23**	**-**	**123.11**	**-18.12**	**-12.8%**
CAREER	16.83	-	16.00	-0.83	-4.9%
Education	**1.82**	**-**	**1.64**	**-0.18**	**-9.9%**
Infrastructure	**-**	**-**	**1.00**	**1.00**	**N/A**
CHESS	-	-	1.00	1.00	N/A

About MCB

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, which assemble into complex structures and compartments with varied functions, contribute to the processes required for life.

Additionally, MCB supports convergence research at the molecular and cellular scales. This basic research at the interface of biological sciences, mathematical, physical, and computer sciences and engineering provide the basis for the quantitative, predictive, theory driven understanding of molecular and cellular functions of biological systems across the tree of life. MCB supported research, for example, contributed to the understanding of the mechanism of deoxyribonucleic acid (DNA) maintenance and repair, and mechanisms of clustered regularly interspaced short palindromic repeats (CRISPR) and CRISPR-associated (Cas) genome editing. Advances in basic research, such as these examples, enable the development of design rules for engineering molecules and cells, and lead directly to biological innovations that enhance medicine, agriculture, biomanufacturing, and contribute to food security and the environment. MCB supported research contributes to the NSF’s Big Ideas: URoL and QL.

In general, about 70 percent of the MCB portfolio is available to support new research grants, and 30 percent is available for continuing grants.

DIVISION OF INTEGRATIVE ORGANISMAL SYSTEMS (IOS) **$168,930,000**
-$23,240,000 / -12.1%

IOS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$192.17**	**-**	**$168.93**	**-$23.24**	**-12.1%**
Research	**182.29**	**-**	**160.23**	**-22.06**	**-12.1%**
CAREER	13.58	-	13.26	-0.32	-2.4%
Education	**3.53**	**-**	**3.13**	**-0.40**	**-11.3%**
Infrastructure	**6.35**	**-**	**5.57**	**-0.78**	**-12.3%**
Research Resources	6.35	-	5.57	-0.78	-12.3%

About IOS

IOS focuses on the organism, the key link between single biological molecules and complex populations. IOS programs support research and education aimed at integrating knowledge across different levels of biological organization to understand the processes that build and maintain organisms. More specifically, IOS activities focus on mechanistic analyses of how biological systems interact and function – spanning the nervous system, growth and development, behavior, and biochemical, biophysical and physiological processes that are integrated to result in stability of organisms living in dynamic environments. Such analysis is fundamental to understanding the principles that produce the vast diversity of life on Earth and the mechanisms that allow for biological adaptation to change.

IOS encourages interdisciplinary science and the development of new approaches through the Enabling Discovery through GEnomic (EDGE) Tools program. Investments in research, including tools for high-throughput analysis of agriculturally-important plants, are maintained as a priority, as is continued support for the NSF-Simons Research Centers for Mathematics of Complex Biological Systems. IOS will continue to leverage its activities across the spectrum of NSF basic science with agricultural research supported by the U.S. Department of Agriculture's National Institutes of Food and Agriculture (NIFA). An example is a partnership between IOS and NIFA to fund research focused on plant biotic interactions.

Results of IOS-supported research are fully consistent with the NSF Big Idea: URoL. IOS's contribution provides information to enable multi-scale biological integration to reveal emergent properties of organisms—spanning the biological diversity from microbes, to plants, to animals. IOS science is highly relevant to societal needs for future food security and sustainability, to understanding the healthy brain, as well as providing new knowledge on how organisms respond to environmental and social stressors.

In general, about 60 percent of the IOS portfolio is available for new research grants, and 40 is available for continuing grants.

DIVISION OF ENVIRONMENTAL BIOLOGY (DEB) **$141,700,000**
-$13,300,000 / -8.6%

DEB Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$155.00**	**-**	**$141.70**	**-$13.30**	**-8.6%**
Research	**152.58**	**-**	**139.68**	**-12.90**	**-8.5%**
CAREER	10.18	-	9.19	-0.99	-9.7%
Education	**2.42**	**-**	**2.02**	**-0.40**	**-16.5%**

About DEB

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 supported research also advances understanding of the functional importance of our natural biodiversity heritage to ecological and ecosystem processes occurring over short- and long-temporal and spatial scales. The discoveries from this research can inform strategies to develop, use, and sustain biological resources, including natural, agricultural, and other managed ecosystems, and to forecast changes in species populations and ecosystems over time.

DEB funded research provides the data, knowledge, and capability to predict 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 environmental drivers of conflict, enhance our ability to strategically prepare for environmental threats, and to field defense and mitigation capabilities that are resilient and adaptive.

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

DIVISION OF BIOLOGICAL INFRASTRUCTURE (DBI) $163,160,000

-$18,150,000 / -10.0%

DBI Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$181.31**	**-**	**$163.16**	**-$18.15**	**-10.0%**
Research	**30.94**	**-**	**32.21**	**1.27**	**4.1%**
CAREER	2.92	-	2.64	-0.28	-9.6%
Centers Funding (total)	21.00	-	16.10	-4.90	-23.3%
Centers for Analysis & Synthesis	6.00	-	4.80	-1.20	-20.0%
STC: Bio/computational Evolution in Action CONsortium (BEACON)	5.00	-	1.30	-3.70	-74.0%
STC: Biology with X-ray Lasers (BioXFEL)	5.00	-	5.00	-	-
STC: Center for Cellular Construction (CCC)	5.00	-	5.00	-	-
Education	**25.69**	**-**	**19.42**	**-6.27**	**-24.4%**
Infrastructure	**124.68**	**-**	**111.53**	**-13.15**	**-10.5%**
NEON[1]	67.90	-	62.60	-5.30	-7.8%
CHESS	4.00	-	-	-4.00	-100.0%
National Nanotechnology Coordinated Infrastructure (NNCI)	0.35	-	0.35	-	-
Research Resources	52.43	-	48.58	-3.85	-7.3%

[1] FY 2018 Actuals figure includes a one-time expenditure of $3.0 million for a cyberinfrastructure enhancements, not related to O&M.

About DBI

DBI empowers biological discovery by supporting the development and enhancement of biological research resources, human capital, and facilities. DBI supports the development of, or improvements to, research infrastructure, including cyberinfrastructure; instrumentation; and improvements to biological research collections, living stock collections, and field stations and marine labs. In addition, DBI supports the development of human capital through undergraduate, and postdoctoral research experiences by participating in the NSF-wide IUSE and Research Experiences for Undergraduate Sites program. DBI also offers a multi-track postdoctoral research fellowships program with special emphasis on emerging areas of the biological sciences. Support for facilities, such as NEON, create opportunities to address targeted but deep biological questions that have major societal impact, particularly with respect to ecological forecasting. NEON is enabling the study of the biosphere and its response to environmental change at a continental scale. Additional infrastructure support will focus on developing capacity of the biological sciences research community through funding cyberinfrastructure and other tools necessary to address the NSF Big Idea: URoL.

In general, about 25 percent of the DBI portfolio is available for new research grants. The remaining 75 percent supports research grants made in prior years and the research infrastructure needed by the biological sciences community.

DIVISION OF EMERGING FRONTIERS (EF) **$83,820,000**
-$1,240,000 / -1.5%

EF Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual: Amount	Change over FY 2018 Actual: Percent
Total	**$85.06**	**-**	**$83.82**	**-$1.24**	**-1.5%**
Research	**84.46**	**-**	**83.82**	**-0.64**	**-0.8%**
Big Idea: URoL	-	-	30.00	30.00	N/A
CAREER	2.03	-	-	-2.03	-100.0%
Education	**0.60**	**-**	**-**	**-0.60**	**-100.0%**

About EF

EF serves as an incubator for innovation and integration within the biological sciences. It supports research that transcends scientific disciplines and advances conceptual foundations across all levels of biological organization. Innovative research and infrastructure activities in BIO typically begin development in EF and then move to other BIO divisions to become part of the disciplinary knowledge base. For example, support for design and early construction of NEON originated within EF but moved to DBI once NEON operations were initiated. EF also facilitates the development and implementation of new forms of merit review and mechanisms to support transformative research and stimulate creativity.

EF also provides the support for BIO participation in national initiatives, NSF priority areas, and other interdisciplinary, cross-division, and cross-directorate programs. Hence, EF is the steward for investments in NSF's Big Idea: URoL.

In general, 51 percent of the EF portfolio is available for new research grants, and 49 percent is available for continuing grants.

DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) $883,040,000 -$77,760,000 / -8.1%

CISE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Office of Advanced Cyberinfrastructure (OAC)	$224.24	-	$199.02	-$25.22	-11.2%
Computing and Communication Foundations (CCF)	195.63	-	172.93	-22.70	-11.6%
Computer and Network Systems (CNS)	231.88	-	205.73	-26.15	-11.3%
Information and Intelligent Systems (IIS)	210.69	-	189.51	-21.18	-10.1%
Information Technology Research (ITR)	98.36	-	115.85	17.49	17.8%
Total	**$960.80**	**-**	**$883.04**	**-$77.76**	**-8.1%**

About CISE

Advances in information technology (IT) over the past two decades have proven to be key drivers of the American economy. Essentially all practical applications of today's IT are based on ideas and concepts that emerged from investments in fundamental computing research.[1] CISE funded basic research in computing has enabled innovative products and applications that permeate many aspects of daily life, including personal communication, 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 American leadership in IT and its applications, including in artificial intelligence (AI) and machine learning (ML), augmented and virtual reality, data science, intelligent civil infrastructure, quantum computing and communication, and advanced research cyberinfrastructure (CI) for all domains, will require sustained investment. CISE will continue to play a major role in funding computing research and training that serve to improve America's economic outlook and advance a highly-trained, technologically astute, and diverse American workforce.

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 CI 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 engineering 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 advanced research CI for all areas of science and engineering; contributes to the education and training of computing professionals; and more broadly, informs the preparation of an American workforce with computing and computational competencies essential for success in an increasingly competitive global and digital market. CISE executes its mission through its CCF, CNS, IIS, and ITR, and through OAC, which has a Foundation-wide role supporting advanced research CI for all areas of science and engineering—and in close partnership with other NSF units, federal agencies, international funders, and the private sector.

CISE investments in FY 2020 will provide continued support for Administration priorities, including basic research in AI, quantum information sciences (QIS), and strategic computing, which are critically important for national security, economic competitiveness, and the broad advancement of all fields of science and engineering. CISE will also continue to invest in advanced manufacturing, and in microelectronics and

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

semiconductor research, promoting continued U.S. leadership in these areas. For example, investments in next-generation manufacturing technologies enabled by AI and ML will help keep jobs in America, ensure products are made in America, and strengthen our national manufacturing industrial base.

CISE's FY 2020 Budget Request is also shaped by continued support for NSF's 10 Big Ideas, including co-leadership of HDR, FW-HTF, and QL. Advances in AI and ML are major components of both HDR and FW-HTF. CISE's FY 2020 Budget Request also comprises support for other ongoing NSF-wide priorities, including IUSE; I-Corps™; and SaTC. In partnership with other NSF directorates and offices, CISE will also participate in the NNA and URoL Big Ideas.

CISE, through OAC and in partnership with other NSF directorates and offices, will lead the all-of-government strategic computing activities previously initiated under the National Strategic Computing Initiative. This activity is described in more detail in the OAC section.

In addition, CISE will continue to provide leadership for the federal government's Networking and Information Technology Research and Development (NITRD) program. The NITRD Subcommittee of the National Science and Technology Council (NSTC), which coordinates investments in networking and information technology research and development across more than 20 federal departments, agencies, and offices, is co-chaired by the NSF assistant director for CISE. All research, education, and research infrastructure projects supported by CISE contribute to NSF's NITRD portfolio. CISE will also continue to co-chair the NSTC Machine Learning and Artificial Intelligence (MLAI) and Open Science Subcommittees.

Finally, CISE will continue to place a priority on developing partnerships with other NSF units, federal agencies, and international funders, and especially with the private sector, including private industry, foundations, and nonprofits, as an increasingly important means to maximize the scientific, economic, and societal impacts of its investments. These external partnerships leverage resources, inform use-inspired research, accelerate the transition of research innovations to practice, and enhance workforce development.

CISE provides about 85 percent of the federal funding for fundamental computer science research at U.S. academic institutions.

Major Investments

CISE Major Investments
(Dollars in Millions)

Area of Investment	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Advanced Manufacturing	$41.27	-	$41.27	-	-
Artificial Intelligence (AI)	284.67	-	309.12	24.45	8.6%
I-Corps™	11.64	-	13.80	2.16	18.6%
IUSE	-	-	2.00	2.00	N/A
Microelectronics and Semiconductors	17.20	-	17.20	-	-
Quantum Information Sciences (QIS)	10.00	-	15.28	5.28	52.8%
SaTC	70.50	-	65.00	-5.50	-7.8%
NSF's Big Ideas					
HDR Stewardship	-	-	*30.00*	*30.00*	*N/A*

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

- Advanced Manufacturing: CISE will invest in research that integrates ubiquitous sensors, computational tools, and highly connected cyber-physical systems in smart processing and cyber-manufacturing systems. This investment will enable new functionalities that will increase the efficiency and sustainability of the production of the next generation of products and services. CISE's investment will also continue support for research on collaborative robotics, i.e., robots that work alongside or cooperatively with people in manufacturing environments to increase their productivity, performance, and safety.

- AI: CISE, together with other NSF directorates/offices, will increase support for AI research and development. A key focal point will be support for *AI Frontiers*, a new center-scale activity that will span (a) foundational areas of ML, computer vision, natural language processing, and autonomy, along with safety, security, robustness, and explainability of AI systems; (b) translational research at the intersection of AI and various science and engineering domains supported by NSF as well as sectors such as agriculture, transportation, and personalized medicine; (c) workforce development, including growing human capital and institutional capacity to nurture a next generation of AI researchers and practitioners; and (d) advanced computing infrastructure, including access to data and compute capabilities enabling AI innovations.

- I-Corps™: CISE, in partnership with the other directorates, will continue to support 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.

- IUSE: Given the increasing centrality of computing to innovation across a wide range of disciplinary and interdisciplinary domains, undergraduate computer science (CS) programs are being called upon to prepare larger and more diverse student populations for careers in both CS and non-CS fields.Many of these students aim to acquire the understandings and competencies needed to learn how to use computation collaboratively across different contexts and challenging problems. Through IUSE: Computing in Undergraduate Education, and together with EHR, CISE will continue to support efforts to re-envision the role of computing in interdisciplinary collaboration within American institutions of higher education.

- Microelectronics and Semiconductors: CISE, together with ENG and MPS, will support research to address fundamental science and engineering questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies. Such progress is critical for emerging technologies such as AI and quantum computing, and will in turn contribute to advances across all sectors of the economy, including energy, transportation, health care, and advanced manufacturing.

- QIS: CISE investments will support research leading to the development of next-generation quantum technologies for sensing, communication, and computing that exploit interactions among particles in quantum systems, offering the promise of dramatic increases in accuracy and efficiency. Developments in QIS could lead to novel algorithms for ML and optimization, along with transformative cybersecurity systems including quantum-resistant cryptography. A key component of CISE's investment in QIS will be to increase capacity in quantum computing and information science within American institutions of higher education

- SaTC: CISE will continue to lead SaTC in partnership with EHR, ENG, MPS, and SBE, investing in current and emerging areas of importance for security and privacy. These areas include the application of AI to security, security and resilience of AI systems, security implications of quantum computation and communication, and critical infrastructure security. These investments will also address education and workforce issues related to cybersecurity and privacy.

- HDR: CISE, as the steward for HDR, will support fundamental research in data science and engineering; development of a cohesive, federated approach to the research data infrastructure; and development of a 21st-century data-capable workforce. Through HDR, CISE will continue to support key foundational programs, including Cyberinfrastructure for Sustained Scientific Innovation (CSSI) and EarthCube, as well as conceptualization activities leading to HDR institutes that will harness diverse data sources and develop new methodologies, technologies, and infrastructure for data management and analysis in national priority areas.

- NSF-wide Education Programs: While CISE will continue to participate in ADVANCE: Organizational Change for Gender Equity in STEM Academic Professions, NSF INCLUDES, and NRT programs in FY 2020, the funds for these NSF-wide education-related programs will be centrally located in EHR.

CISE Funding for Centers Programs and Facilities

CISE Funding for Centers Programs
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$9.94**	**-**	**$6.30**	**-$3.64**	**-36.6%**
STC: Center for the Science of Information (CCF)	4.94	-	1.30	-3.64	-73.7%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence (CCF, IIS, ITR)	5.00	-	5.00	-	-

For detailed information about NSF Centers programs, please see the NSF-Wide Investments chapter.

Funding Profile

CISE Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	9,151	-	9,600
Number of New Awards	2,099	-	1,900
Funding Rate	23%	N/A	20%
Statistics for Research Grants:			
Number of Research Grant Proposals	8,749	-	9,180
Number of Research Grants	1,823	-	1,650
Funding Rate	21%	N/A	18%
Median Annualized Award Size	$166,309	-	$165,000
Average Annualized Award Size	$199,292	-	$200,000
Average Award Duration, in years	2.9	-	3.0

Program Monitoring and Evaluation

Committees of Visitors (COVs):

- In early FY 2018, OAC convened a COV to examine and assess the quality of the merit review process across OAC. The report from that COV was accepted by the Advisory Committee for Cyberinfrastructure (ACCI) at its Spring 2018 meeting.[2]
- In late 2019, CISE will convene a COV to review FY 2014-FY 2018 programs in its CCF, CNS, and IIS divisions.

Program Evaluations:

- In FY 2012, the Science and Technology Policy Institute (STPI) conducted a program evaluation feasibility study for SaTC. This feasibility study provided methods for examining baseline portfolio investments and identifying metrics to measure progress toward program goals. The study was part of a broader effort to develop a plan for a future impact assessment. STPI identified baseline evaluation metrics in FY 2013-FY 2015 and completed the evaluation feasibility study in FY 2016. CISE, together with the NSF Evaluation and Assessment Capability, funded a program evaluation of SaTC in FY 2016; that program evaluation is anticipated to be completed by the end of FY 2019.
- Evaluation is a key part of all of CISE's education programs. K-12 computer science education projects managed by CISE include rigorous research and evaluation plans designed to guide project progress and measure project impacts. CISE has also funded a third-party evaluation across individual teacher professional development projects at the high school level. The evaluators for these activities meet regularly, discuss evaluation issues, and contribute statistics to a common dataset in order to track program-level progress. CISE expects to continue these evaluation activities in FY 2020.

With BIO, CISE is co-leading NSF's Agency Priority Goal (APG) to expand public and private partnerships agency-wide in order to enhance the impact of NSF's investments and contribute to American economic competitiveness and security. As part of this APG, NSF is conducting an inventory and analysis of NSF public and private partnerships that will help inform the strategy for partnerships in the future.

Reports:

- CISE has funded several studies led by the Computer Science and Telecommunications Board (CSTB) within the National Academies of Sciences, Engineering, and Medicine that resonate with the directorate's FY 2020 investments:
    - Over the last decade, CISE has funded the CSTB to study the IT innovation ecosystem and assess the long-term economic impacts of CISE investments. For example, a 2009 report, *Assessing the Impacts of Changes in the Information Technology R&D Ecosystem*,[3] provides an in-depth articulation of the creation of almost 20 IT industries since 1965 valued at a minimum of $1 billion each. A 2012 report, *Continuing Innovation in Information Technology*,[4] identified additional IT industries that had reached the billion-dollar mark, and noted the nature and successes of U.S. research partnerships among government, industry, and universities, and the economic payoffs of these research investments. In FY 2017, CISE funded CSTB to update the so-called "tire-tracks" diagram[5] from the 2012 report, depicting the interconnections across research areas and with the creation and evolution of IT industry sectors.[6]

[2] www.nsf.gov/od/oia/activities/cov/covs.jsp#cise
[3] www.nap.edu/catalog.php?record_id=12174
[4] www.nap.edu/catalog.php?record_id=13427
[5] http://sites.nationalacademies.org/CSTB/CSTB_181872
[6] www.nsf.gov/awardsearch/showAward?AWD_ID=1748756&HistoricalAwards=false

- *Toward 21st-Century Cyber-Physical Systems Education:* a 2016 report 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.[7]
- *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science in 2017-2020:* a 2016 report 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 U.S. 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.[8] Recommendations from the report have led to new programs, including a solicitation for the initial phase of a leadership-class computing facility in FY 2018 (see the Advanced Computing Appendix in this narrative for more information).
- *Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?:* a 2017 report 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.[9]
- *Growth of Computer Science Undergraduate Enrollments:* a 2017 report recommending responses to growing undergraduate computer science enrollments, including: (1) bringing computer science faculty and institutional leaders together to identify best practices and innovation in computer science education across the entire student body; (2) conducting research on how best to use technology in teaching large classes, and on best practices for supporting diversity in computing; and (3) expanding instructional resources for undergraduate computer science education.[10]
- *Envisioning the Data Science Discipline: The Undergraduate Perspective:* a 2018 report offering a vision for the emerging discipline of data science at the undergraduate level along with considerations and approaches for academic institutions and others to help guide the ongoing transformation of the field.[11]
- *Quantum Computing:* a 2018 report assessing the current progress and possible future pathways toward developing a general-purpose quantum computer as well as its potential implications.[12]

- The Computing Community Consortium (CCC) has led several community visioning efforts that resonate with the directorate's FY 2020 investments:
  - *Computing Visions 2025:* inspired the CISE research community to envision future trends and opportunities in computer and information science and engineering research. Two workshops were held under this activity: *Interacting with Computers All Around Us*, and *The New Making Renaissance: Programmable Matter and Things.*[13]
  - *Intelligent Infrastructure:* jointly with the Electrical and Computer Engineering Department Heads Association, 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 enhancing efficiency, resiliency, and safety.[14]
  - *Next Steps in Quantum Computing: Computer Science's Role:* brought together researchers from quantum computing, computer architecture, electronic design automation, compiler construction,

[7] www.nap.edu/catalog/23686/a-21st-century-cyber-physical-systems-education
[8] www.nap.edu/catalog/21886/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-and-engineering-in-2017-2020
[9] www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[10] www.nap.edu/catalog/24926/assessing-and-responding-to-the-growth-of-computer-science-undergraduate-enrollments
[11] www.nap.edu/catalog/25104/data-science-for-undergraduates-opportunities-and-options
[12] www.nap.edu/catalog/25196/quantum-computing-progress-and-prospects
[13] https://cra.org/ccc/visioning/computing-visions-2025/
[14] https://cra.org/ccc/resources/ccc-led-whitepapers/#infrastructure

and classical programming languages to articulate the central role that various CISE subfields play to close the gap between the problems for which a quantum computer might be useful and what we can currently build, program, and run.[15]

- *Fair Representations and Fair Interactive Learning:* brought together researchers from academia, industry, and government to identify key challenges underlying the science of fairness in ML, with a particular focus on theoretical work aimed at providing a scientific foundation for understanding algorithmic bias.[16]
- *Artificial Intelligence Roadmap:* developing a roadmap for AI research priorities over the next 20 years, including key challenges, opportunities, and pitfalls.[17]

- CISE-funded community workshops also resonate with the directorate's FY 2020 investments. For example, a January 2018 workshop on *Enabling Computer and Information Science and Engineering Research and Education in the Cloud* brought together researchers from academia, industry, and government to discuss ways to enable the CISE community to effectively utilize cloud computing resources.[18]

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

People Involved in CISE Activities

Number of People Involved in CISE Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	7,837	-	7,200
Other Professionals	1,158	-	1,000
Postdoctoral Associates	455	-	400
Graduate Students	6,598	-	6,100
Undergraduate Students	2,741	-	2,500
Total Number of People	**18,789**	**-**	**17,200**

[15] https://cra.org/ccc/events/quantum-computing/
[16] https://cra.org/ccc/events/fair-representations-fair-interactive-learning/
[17] https://cra.org/ccc/visioning/visioning-activities/2018-activities/artificial-intelligence-roadmap/
[18] https://dl.acm.org/citation.cfm?id=3233928

OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC) **$199,020,000**
-$25,220,000 / -11.2%

OAC Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$224.24**	**-**	**$199.02**	**-$25.22**	**-11.2%**
Research	**96.22**	**-**	**74.82**	**-21.40**	**-22.2%**
CAREER	1.80	-	1.60	-0.20	-11.1%
Education	**9.64**	**-**	**6.70**	**-2.94**	**-30.5%**
Infrastructure	**118.39**	**-**	**117.50**	**-0.89**	**-0.8%**
Networking and Computational Resources Infrastructure and Services	118.39	-	117.50	-0.89	-0.8%

About OAC

OAC supports the conceptualization, design, and implementation of the advanced research CI ecosystem that is critical to advances in all areas of science and engineering research and education in the 21st century, and in this way, serves to sustain U.S. economic competitiveness and national security. Given its role across all of science and engineering, OAC works in partnership with all NSF directorates and offices as well as other CISE divisions, to provide support to academic institutions encourages a rich and vibrant ecosystem that blends translational computer and computational research and research-specific CI 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 data services, and the design and 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. Collectively, OAC enables more than 8,000 faculty and researchers to address complex and multidisciplinary discovery, prediction, and innovation challenges by providing access to CI resources and services, along with secure connectivity to major international facilities and scientific instruments. OAC promotes innovative, robust, secure, and interoperable CI, as well as sharing and collaboration among academic research infrastructure groups, other federal agencies and international research funders, and the private sector.

OAC, in partnership with other NSF directorates and offices, will lead the all-of-government strategic computing activities previously initiated under the National Strategic Computing Initiative. This activity will support research advances in new computing technologies, architectures, and platforms for the future, as well as the development and deployment of advanced computing systems and services, including maximizing the benefits of these systems and services through the deep integration with science and engineering research. These investments will enable shared resources and improved capabilities across a range of disciplines and will enable a broad set of users within a large number of academic institutions.

In general, about 51 percent of the OAC portfolio is available to support new grants. The remaining 49 percent supports grants made in prior years.

DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS (CCF)

$172,930,000
-$22,700,000 / -11.6%

CCF Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$195.63**	**-**	**$172.93**	**-$22.70**	**-11.6%**
Research	**183.93**	**-**	**164.33**	**-19.60**	**-10.7%**
CAREER	18.06	-	15.96	-2.10	-11.6%
Centers Funding (total)	7.94	-	4.30	-3.64	-45.8%
STC: Center for the Science of Information	4.94	-	1.30	-3.64	-73.7%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	3.00	-	3.00	-	-
Education	**11.10**	**-**	**8.00**	**-3.10**	**-27.9%**
Infrastructure	**0.60**	**-**	**0.60**	**-**	**-**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.60	-	0.60	-	-

About CCF

CCF supports research and educational activities that study the theoretical foundations of computing, communication, and information. CCF supports exploring the fundamental limits of computation, communication, and information across analog, digital, quantum, and biological domains; advancing algorithmic knowledge for research areas within and outside computer science; and furthering software and hardware design. CCF's research investments enable advances in the design and analysis of algorithms, computational complexity, theoretical and experimental studies of algorithms and their resource requirements, and mathematical models of computation, including approaches for parallel, distributed, and heterogeneous multi-core machines. CCF also invests in foundational research on 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 improving performance, correctness, usability, reliability, and scalability. CCF research also explores the potential impact of emerging technologies on computation, communication, and information, including quantum devices and systems, neuromorphic computation, nanotechnology, and biocomputing.

In general, about 72 percent of the CCF portfolio is available to support new grants. The remaining 28 percent supports grants made in prior years.

DIVISION OF COMPUTER AND NETWORK SYSTEMS (CNS) **$205,730,000**
-$26,150,000 / -11.3%

CNS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$231.88**	**-**	**$205.73**	**-$26.15**	**-11.3%**
Research	**189.83**	**-**	**168.63**	**-21.20**	**-11.2%**
CAREER	10.05	-	8.91	-1.14	-11.3%
Education	**15.97**	**-**	**11.10**	**-4.87**	**-30.5%**
Infrastructure	**26.09**	**-**	**26.00**	**-0.09**	**-0.3%**
Research Resources	26.09	-	26.00	-0.09	-0.3%

About CNS

CNS supports 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, cloud, wireless, and mobile systems. CNS also supports research and education activities in cybersecurity 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, about 75 percent of the CNS portfolio is available to support new grants. The remaining 25 percent supports grants made in prior years.

DIVISION OF INFORMATION AND INTELLIGENT SYSTEMS (IIS) **$189,510,000**
-$21,180,000 / -10.1%

IIS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$210.69**	**-**	**$189.51**	**-$21.18**	**-10.1%**
Research	**199.73**	**-**	**181.51**	**-18.22**	**-9.1%**
CAREER	21.24	-	19.10	-2.14	-10.1%
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	**10.96**	**-**	**8.00**	**-2.96**	**-27.0%**

About IIS

IIS supports research that studies the interrelated roles of people, computers, and information. Specifically, IIS supports research and education in AI, data science, and human-computer interaction. Research in AI includes machine learning, knowledge representation, computer vision, and natural language processing. Research in data science includes data management, data collection, data analytics, and data integration. Research in human-computer interaction includes work on computer system usability, new kinds of user interfaces, and computer systems to augment human capabilities. Research supported by IIS addresses fundamental questions about machine intelligence, helps us understand how data can improve our lives, and lays the foundation for innovations in a myriad sectors including energy, transportation, healthcare, manufacturing, and defense.

In general, about 81 percent of the IIS portfolio is available to support new grants. The remaining 19 percent supports grants made in prior years.

DIVISION OF INFORMATION TECHNOLOGY RESEARCH (ITR) $115,850,000 +$17,490,000 / 17.8%

ITR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$98.36**	**-**	**$115.85**	**$17.49**	**17.8%**
Research	**85.37**	**-**	**105.85**	**20.48**	**24.0%**
Big Idea: HDR	-	-	30.00	30.00	N/A
CAREER	1.53	-	-	-1.53	-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	**2.81**	**-**	**-**	**-2.81**	**-100.0%**
Infrastructure	**10.18**	**-**	**10.00**	**-0.18**	**-1.8%**
Research Resources	10.18	-	10.00	-0.18	-1.8%

About ITR

ITR provides support for transformative explorations in computer and information science and engineering research, infrastructure, and education, emphasizing the funding of innovative, high-risk/high-reward, multi-investigator projects. ITR investments support emerging and urgent high-priority areas of potentially transformative research that cut across traditional disciplinary boundaries and promise to accelerate discovery at the frontiers of computer and information science and engineering. This includes support for fundamental research on advanced networking, physical sensors/devices and large-scale data management, analysis and decision making; innovative partnerships and collaborations between academia and industry; as well as the development of world-class research infrastructure. This is done in partnership with all of the CISE divisions as well as through cross-NSF and interagency activities.

ITR, in partnership with all of the NSF directorates and research offices, will advance the HDR Big Idea by investing funds to support convergent activities that transcend the traditional disciplinary boundaries of individual NSF directorates and offices. These activities will enable 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. While budget management and reporting for this investment will be the responsibility of CISE, the convergent activities will be overseen and managed collaboratively by the multi-directorate/office HDR leadership team.

In general, about 53 percent of the ITR portfolio is available to support new grants. The remaining 47 percent supports grants made in prior years.

APPENDIX A – ADVANCED COMPUTING PORTFOLIO

Advanced Computing Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Leadership-Class Computing	$60.12	-	$20.00
Advanced/Innovative Computing Systems and Services	13.81	-	40.00
Coordination and Support Services	8.00	-	22.00
Total	**$81.93**	**-**	**$82.00**

For nearly four decades, NSF has been a recognized leader in enabling the innovative use and broad availability of a cohesive, powerful, and advanced computing ecosystem to accelerate fundamental science and engineering. NSF aims to sustain America's leadership in the research, development, and broad deployment of existing as well as new advanced computing technologies, services, and skills—and aims to do so in part through leadership of the all-of-government strategic computing activities previously initiated under the National Strategic Computing Initiative[19] jointly with the Department of Defense and Department of Energy, and in concert with other participating federal agencies as well as the private sector. Within the broad goals set for the all-of-government strategic computing activities, key NSF 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 applications; and support for a comprehensive advanced computing ecosystem for science and engineering research.[20] These foci include an emphasis on a holistic approach to America's computational infrastructure for science and engineering research, spanning both human and technical dimensions.

The overall NSF advanced computing strategy and program portfolio receives guidance and input from the Advisory Committee for Cyberinfrastructure (ACCI); Assistant Directors (AD) Council, which includes ADs and Office Heads from the various NSF research and education directorates and offices; cross-directorate working group for strategic computing; and directly from the research community through Principal Investigators' meetings, workshops, and sessions at professional conferences.[21] In 2013, OAC supported a National Academies of Sciences, Engineering, and Medicine study to further inform the implementation of its advanced computing strategy in the 2017 to 2020 timeframe; the final report, *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering in 2017-2020*, was published in 2016.[22] In 2017, OAC launched an effort to refresh the vision, strategy, and investment approaches for cyberinfrastructure, including advanced computing, to support the evolving needs of the science and engineering community,[23] and also funded a study seeking to identify and catalog best practices for collaborations between academic or federally-funded High-Performance Computing (HPC) centers and industry.[24] In 2018, NSF funded a workshop focused on "Future Cyberinfrastructure: Rethinking NSF's Computational Ecosystem for 21st-Century Science and Engineering."[25] International activities to accelerate investments in leadership-class computing, particularly in Europe and Asia, are

[19] www.nitrd.gov/nsci/
[20] www.nsf.gov/cise/nsci/
[21] See, for example, https://sc18.supercomputing.org/presentation/?id=bof154&sess=sess417
[22] www.nap.edu/catalog/21886/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-6
[23] www.nsf.gov/cise/oac/ci2030/
[24] www.ncsa.illinois.edu/assets/pdf/industry/Industry_Report_2017.pdf
[25] https://uiowa.edu/nsfcyberinfrastructure/article/workshop-report

providing additional urgency and importance for this investment strategy to ensure the U.S. maintains its global leadership role in science and engineering.

Technological advances come rapidly, and the capabilities and services offered by commercial interests (e.g., cloud) also change rapidly. The requirements of the science and engineering research communities are both heterogeneous and dynamic. To meet these continually evolving needs in an agile yet predictable way, NSF currently invests in three broad and complementary advanced computing areas: Leadership-Class Computing; Advanced/Innovative Computing Systems and Services; and Coordination and Support Services. These resources and services complement each other as well as discipline-specific investments by NSF's directorates, mission-specific investments by other agencies, and cumulatively extensive but individually smaller investments by academic institutions at the regional and campus levels. Specifically:

- **Leadership-Class Computing** (formerly Petascale Computing) aims to provide unique services and resources to advance the largest and most computationally-intensive science and engineering research frontiers not otherwise possible;
- **Advanced/Innovative Computing Systems and Services** (formerly Innovative HPC Program) aims to provide a technically diverse and potentially future-looking advanced computing portfolio, reflecting the growing and changing use of computation and data in both the research and education processes, and capable of supporting hundreds to thousands of investigators conducting cutting-edge science and engineering research; and
- **Coordination and Support Services** (formerly Extreme Digital) aims to coordinate the provisioning, allocation, and operations of NSF's advanced computing resources, providing advanced assistance to the user community, supporting aggregation and federation capabilities, and broadening participation.

Leadership-Class Computing

<u>Description</u>

Leadership-class computing systems have represented a key component of NSF's computational portfolio for decades. NSF's current leadership-class computing resource is Blue Waters, which is deployed at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC). Since it became operational in FY 2013, Blue Waters has allowed researchers to tackle much larger and more complex challenges than ever before, within and across disciplines as diverse as biology, astronomy, engineering, materials science, and the geosciences.

Despite the success of Blue Waters, this computing resource is reaching its natural end of life and will complete its operational cycle in December 2019. NSF's next leadership-class computing system will be the recently-funded Frontera system. Frontera will be deployed by the Texas Advanced Computing Center (TACC) at the University of Texas at Austin (UT Austin) and is expected to be among the largest central processing unit (CPU)-based systems in the world and among the most powerful supercomputers ever deployed on a U.S. academic campus when it becomes operational. The system is expected to begin accepting early science and engineering research users in May 2019 and to be fully operational by July 2019.

<u>Current Status</u>

As noted above, the Blue Waters system is nearing its natural end of life. 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. The award was granted a no-cost extension in FY 2016 that runs through mid-FY 2019. A second extension granted at the end of calendar year 2018 will allow the system to operate through December 2019, enabling a seamless transition from Blue Waters to the recently-awarded Frontera system at TACC. With the extension of the operational end date of Blue Waters through 2019, the system will have run for roughly three years longer than the typical lifetime for a system of this type, providing excellent return on federal investment.

In anticipation of the operational end date of Blue Waters in FY 2016, NSF developed a plan for a phased approach to support a next-generation, leadership-class computing system. This plan was discussed with the National Science Board (NSB) in FY 2017, and in May 2017, NSF issued a competitive solicitation[26] for the first phase (Phase 1) of a two-phase plan to deploy a new leadership-class computing facility. The solicitation called for a Phase 1 system that would be two to three times more powerful in application performance than Blue Waters. The system acquisition was awarded in FY 2018, and will be followed by a separate award for an operations and maintenance (O&M) phase, anticipated to commence in FY 2019 and last for five years.

Following the Phase 1 solicitation and associated review process of the submitted proposals, NSB at its July 2018 meeting authorized the Director at her discretion to make an award to the TACC for the acquisition of the Frontera system in an amount not to exceed $60.0 million over a period of five years. The resolution also authorized that, pending appropriate approval associated with NSF's Major Research Equipment and Facilities Construction (MREFC) policies, an additional amount not to exceed $8.0 million may be made available to TACC in the form of supplemental funding to this award to advance the design of the Phase 2 leadership-class computing system. NSF issued an award to the University of Texas at Austin for the acquisition of Frontera in September 2018.

When deployed, the Frontera system will offer the highest scale, throughput, and data analysis capabilities ever deployed on a university campus in the U.S. TACC is building the supercomputer, with the primary computing system provided by Dell EMC and powered by Intel processors. Through its primary CPU subsystem, Frontera will offer more than five times greater capacity than the previous leadership-class NSF-funded computing system. In addition, Frontera's graphics processing unit (GPU) will accelerate discoveries in dynamic research areas such as deep learning and molecular dynamics. The system will also allow science and engineering evaluation to inform the design of a future leadership-class computing facility.

<u>Science and engineering research and education activities enabled by Leadership-Class Computing</u>

Leadership-class computing systems enable investigators across the country to conduct innovative research that is not otherwise possible due to demanding technical requirements. Over its lifetime, the Blue Waters project has supported more than 700 project teams, the majority of them through the highly competitive NSF Petascale Computing Resource Allocations (PRAC) program. The research topics that 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. For the transition period between Blue Waters and Frontera, NSF has issued a Dear Colleague Letter[27] accepting applications for supplements to active NSF research awards for time on both systems.

Education and outreach projects are ongoing; they target pre-college, undergraduate, graduate, and post-graduate students. The Blue Waters project also sponsors workshops, conferences, summer schools, and seminars. The project includes industry partnership activities as well. The Industry Partners in Petascale Engagement program provides industry partners across a wide range of market sectors (e.g., health, energy,

[26] www.nsf.gov/pubs/2017/nsf17558/nsf17558.htm
[27] www.nsf.gov/pubs/2019/nsf19030/nsf19030.jsp

advanced manufacturing) with expertise as well as a first look at the technological and scientific developments that flow from the petascale program. To date, there have been more than 200 education, outreach, and training projects engaging over 3,700 individuals at over 160 institutions, including 41 institutions in Established Program to Stimulate Competitive Research (EPSCoR) jurisdictions and 14 Minority-Serving Institutions.

Management and Oversight

The Blue Waters and Frontera projects are overseen by OAC's program directors and BFA's Division of Grants and Agreements staff, who receive strategic advice from the AD Council. Advice from the NSF Office of General Counsel is also sought, as necessary.

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

Advanced/Innovative Computing Systems and Services

Description

NSF funds the acquisition and operation of nationally-available Advanced/Innovative Computing Systems and Services that, in aggregate, are forward-looking and technically diverse, and reflect changing and growing use of data-intensive computation in both the research and education processes. At the same time, they are intended to enable discoveries at a computational scale beyond the reach of an individual or regional academic institution.

Deployed systems serve as a cohesive set of allocable resources within the eXtreme Digital (XD) integrated services infrastructure, which is described in the following section. Advanced/innovative computing systems and services awards are generally made as two parts: an acquisition and deployment award that may be the result of a competitive or a renewal proposal; and a separate award for operations and maintenance following deployment. When an award is made, the awardee institution issues sub-awards to vendors and/or other organizations for acquisitions and services as necessary. Expenditures are contingent on successful completion of deployment milestones.

Current Status

Four resources, Wrangler, Comet, Bridges, and Jetsream, commenced operations in FY 2015 and FY 2016, and the capabilities of Comet, Bridges, and Jetstream have been augmented since initial deployment. In FY 2018, the period of operation for these four systems was extended, as noted below, allowing for increased return on investment and ensuring continuity of operations for the research community. Stampede 2, the largest of the currently active HPC resources within this portfolio, commenced operation in FY 2017. NSF will continue to diversify its portfolio of advanced/innovative computing systems and services to address the evolving and broadening needs of the research community.

Deployed in FY 2015, Wrangler is the most powerful data analysis system allocated in XD, with 10 petabytes of replicated, secure, high-performance data storage. This innovative 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 and 275 million Input/Output Operations Per Second (IOPS). Wrangler provides flexible support for a wide range of software stacks, including Hadoop and relational data. Support for ongoing Wrangler operations and maintenance continues through October 2019, and is provided to UT 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.[28] Wrangler's 275 million IOPS capabilities remain at the leading edge of currently deployed systems in production operations; the extension provides for continuing operations at that performance level.

Comet also came online in FY 2015 at the University of California, San Diego (UCSD). It supports research interests and priorities requiring large, high-throughput workloads, which in turn prompt massive amounts of computation but at moderate scalability. Notably, as a resource responsive to the "long tail of science," Comet is particularly well-suited for the large-scale computational needs of research community portals such as Cyberinfrastructure for Phylogenetic Research as well as distributed workflows such as those required by the Laser Interferometer Gravitational-Wave Observatory. Comet's heterogeneous configuration supports not only complex simulations but also advanced analytics and visualization of outputs. As a result of its role in machine learning, visualization, and advanced analytics, supplemental funding was provided to increase the GPU component of Comet in FY 2017. Comet is planned to remain operational through March 2021.

Bridges came online in FY 2016 at the Pittsburgh Supercomputing Center on the campus of Carnegie Mellon University (CMU). Bridges provides an innovative and groundbreaking HPC and data analytics system integrating advanced memory technologies to empower new communities. It brings desktop convenience to HPC, connecting to campuses, and intuitively integrating data-intensive workflows to increase the output of a large community of scientific and engineering researchers that has not traditionally used HPC resources. Bridges extends the impact of HPC to EPSCoR jurisdictions and Minority-Serving Institutions, raising the level of computational awareness at four-year colleges, and promoting computational thinking in high-schools. Bridges was augmented with GPU nodes in FY 2018 and will remain operational through November 2020.

Jetstream also came online in FY 2016 at Indiana University. Jetstream is a cloud-based platform that incorporates the best elements of commercial cloud computing resources with some of the best software for solving important scientific problems. Jetstream enables new modes of sharing data and computational analysis, allowing for increased scientific reproducibility and enabling American scientists and engineers to make new discoveries that are important to understanding the world around us, thereby improving the quality of life for all Americans and promoting the nation's competitive standing in the world. Jetstream's system operation was augmented in FY 2017 to provide additional focused staff expertise to accelerate effective researcher utilizations of the programmable cyberinfrastructure/virtual machine-enabled architecture. The system will continue operations through November 2020.

In FY 2016, NSF awarded *Stampede 2: The Next Generation of Petascale Computing for Science and Engineering* to UT Austin following a rigorous merit review, enabling the acquisition, development, and deployment of Stampede 2 as a successor resource to the highly successful Stampede system. Stampede operated from 2013 through 2017 and was considered the "backbone" for the XD environment, annually supporting more than 5,000 researchers and more than 1,000 computationally-intensive projects across the Nation. Stampede 2 similarly serves as the primary national resource (i.e., the "workhorse") for thousands of American academic researchers, complements other national advanced computing systems and services, and provides capabilities beyond the reach of individual campuses and regional resources, including support for multiscale modeling, simulation, and data-intensive research. Stampede 2 has been deployed into production operation through three phases: (1) the Intel Knights Landing many-core nodes were deployed in 2017, demonstrating increased performance at lower power rates; (2) the highly complementary Intel SkyLake processors, which are responsive to data-intensive computing, were in early operations in 2017 and fully deployed as a peak 18-petaflop system in 2018; and (3) the final deployment phase, also in 2018, introduced persistent memory to the previously-deployed Skylake processors to significantly enhance

[28] www.nsf.gov/pubs/2013/nsf13528/nsf13528.htm

overall system performance. Stampede 2 will serve the high-end, open science community through November 2022.

As noted above, Wrangler, Comet, Bridges, and Jetstream are all scheduled to ramp down operations during FY 2020 through FY 2021. During the same period, Stampede 2 will continue at full operation and the new leadership-class computing system, Frontera, will ramp up to full operations to ensure continued support for the science and engineering research community. Moving forward, NSF envisions that investments in advanced/innovative computing systems and services will foster an integrated cyberinfrastructure ecosystem that addresses the growing scale and diversity of the science and engineering community, the changing nature of science and engineering research requirements, and the rapidly evolving technology and services landscape, with the overarching goal of supporting the full range of computational- and data-intensive research across all science and engineering domains. To further this goal, NSF issued a solicitation for advanced computing systems and services in FY 2019 with anticipated awards spanning FY 2019-FY 2024.[29] This solicitation calls for investments in two categories:

- Category I, Capacity Systems: production computational resources maximizing the capacity provided to support the broad range of computation and data analytics needs in science and engineering research; and
- Category II, Innovative Prototypes/Testbeds: innovative forward-looking capabilities deploying novel technologies, architectures, usage modes, etc., and exploring new target applications, methods, and paradigms for science and engineering discoveries.

The solicitation will remain in effect through FY 2020, allowing for two cycles of submissions and awards.

Science and engineering research and education activities enabled by Advanced/Innovative Computing Systems and Services

The ecosystem of advanced/innovative computing systems and services is enabling new, world-leading, and transformative advances across the breadth of science and engineering research, in the integration of research and education, and in broadening participation in science and engineering by underrepresented groups. It is enabling new collaborations across public and private sectors to advance American security and economic competitiveness. These advances are made possible by providing researchers and educators with usable access to world-leading computational systems and services, together with expertise, beyond that typically available on most campuses, including the interfaces, consulting support, and training necessary to facilitate use of the systems and services. This activity is central to America achieving the full potential of complementary investments by NSF, other federal agencies, and academic institutions.

Management and Oversight

OAC's program directors provide direct oversight during both the acquisition and operations and maintenance awards. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors.

Awards for advanced/innovative computing system and services are managed under cooperative agreements that include the management structures, milestones, spending authorization levels, and review schedules. Each awardee is responsible for the satisfactory completion of milestones prior to NSF authorization of spending. Progress is assessed with the aid of annual external reviews. In addition, each project is required to have a project management plan.

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. During the award process, risks are identified and analyzed, and a mitigation

[29] www.nsf.gov/pubs/2019/nsf19534/nsf19534.htm

plan is created and followed. One of the activities of the periodic NSF external reviews, conducted by an external panel of experts, is to revisit and reassess the risk situation and make recommendations as deemed necessary. In the case of projects that involve an acquisition, typically, project risks are substantially reduced subsequent to deployment. Thus, the pacing of the acquisitions and deployments for such projects provides balance in the overall risk portfolio for the program.

Milestone-driven reviews occur during the acquisition award, typically with an external review prior to deployment. Annual reviews, conducted by an external panel of expert reviewers and managed by OAC program directors, are performed during the operational phase of each project.

Coordination and Support Services

Description

NSF's investments in coordinaton and support services, as exemplified by the XD integrated services infrastructure, add value to the NSF advanced/innovative computing systems and services by coordinating the systems and services, providing advanced assistance to the user community, and broadening participation. The XD program's shared services model for coherently and efficiently delivering to researchers both access and expertise to diverse, dynamic, and distributed resources is a cornerstone of the American advanced computing, including HPC, ecosystem. Enabling the connection between individual campuses and national resources is an essential aspect of the advanced computing ecosystem.

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. 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: XD Metrics Service (XMS) and the eXtreme Science and Engineering Discovery Environment (XSEDE). The smaller XMS award was made in FY 2015 to The State University of New York at Buffalo. This award provides metrics services allowing measurement of key operational data for both resources and services. All other services are provided by XSEDE. The XSEDE award to UIUC was renewed in September 2016, continuing the prior XSEDE award for another five-year period. The award will conclude at the end of August 2021, and in anticipation of that date, NSF has initiated engagements with the community about the structure and composition of future coordination efforts.

Within the current XSEDE project, there are 18 partners engaged via subawards to the University of Tennessee at Knoxville (National Institute for Computational Sciences), CMU and University of Pittsburgh (Pittsburgh Supercomputing Center), UT Austin (TACC), UCSD (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, Georgia Institute of Technology, Oklahoma State University, University of Georgia, Oklahoma University, University of Southern California, and University of Arkansas.

The mid-project external site review of the XMS project took place in June 2018 and continued operations were authorized based on the successful outcome of that review. XSEDE has annual external reviews at NSF. The first external review of the renewed XSEDE project took place in June 2017; subsequent external milestone reviews have taken place in January and June 2018. On the basis of these successful reviews, funds have been authorized for operations through the third year of the five-year award.

Science and engineering research and education activities enabled by Coordination and Support Services

Coordination and support services, as exemplified by XD, enable transformative advances in science and engineering research, in the integration of research and education, and in broadening the participation of underrepresented groups in science and engineering. These advances are 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 coordinates access to advanced/innovative computing systems and services and enables researchers to efficiently manipulate, analyze, visualize, and share extremely large amounts of distributed digital information from simulations, sensors, and experiments.

XD's XSEDE project delivers 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 dynamic 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 barriers to the use of advanced digital systems by the research and education communities, thereby promoting enhanced productivity.

XD's XMS project develops analysis tools and collects operational data from XD projects such as XSEDE and the advanced computing/innovative systems and services. The immediate users of these methods and tools are the providers of NSF-supported advanced computing systems and services. However, both tools and data are publicly available and used by other projects such as Blue Waters, Frontera, and individual universities.

Management and Oversight

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.

Each XD award is managed under a cooperative agreement that includes requirements for a specific management structure, milestones, reporting of spending levels over time, and a review schedule. Each awardee is responsible for the satisfactory completion of milestones prior to NSF authorization of spending. In addition, each project is required to have a detailed management plan in place.

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.

Annual reviews for XSEDE and mid-project reviews for XMS are conducted by external panels of expert reviewers and managed by OAC program directors.

DIRECTORATE FOR ENGINEERING (ENG) **$881,420,000**
-$96,480,000 / -9.9%

ENG Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Chemical, Bioengineering, Environmental and Transport Systems (CBET)	$187.19	-	$169.43	-$17.76	-9.5%
Civil, Mechanical, and Manufacturing Innovation (CMMI)	236.95	-	204.00	-32.95	-13.9%
Electrical, Communications, and Cyber Systems (ECCS)	116.05	-	105.04	-11.01	-9.5%
Engineering Education and Centers (EEC)	116.71	-	92.60	-24.11	-20.7%
Industrial Innovation and Partnerships (IIP)	271.71	-	245.25	-26.46	-9.7%
Emerging Frontiers and Multidisciplinary Activities (EFMA)	49.28	-	65.10	15.82	32.1%
Total	**$977.90**	-	**$881.42**	**-$96.48**	**-9.9%**

About ENG

In FY 2020, ENG will invest in fundamental engineering research and in Administration and NSF-wide research priorities that contribute to America's security, prosperity, health, and technological leadership. Substantial directorate investments—in the NSF Big Ideas and the new generation of NSF Engineering Research Centers (ERCs)—will emphasize convergence research approaches to help address grand challenges and societal needs. In addition, to advance U.S. global competitiveness, strategic ENG support will strengthen the engineering workforce and accelerate innovation by high-tech small businesses and industry.

To help protect the American people, ENG investments will drive advances in quantum technologies for secure communication systems, as well as sensing and information systems as part of the QL Big Idea. ENG will continue its long-term support of engineering research to improve resilience to hurricanes, earthquakes, and other disasters through the Natural Hazards Engineering Research Infrastructure (NHERI) and other programs. Other ENG-funded research will investigate methods and technologies for securing the electric grid, detecting biological threats, and disrupting illicit supply networks.

To enhance U.S. economic and technologic leadership, ENG will steward the FW-HTF Big Idea, while its convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. ENG will also make critical contributions to FW-HTF through foundational research on soft robotics, embodied intelligent cognitive assistants, and artificial intelligence.

ENG collaboration in the HDR Big Idea will intersect with support for advanced materials and devices, smart systems and connected communities, and disruptive technologies for energy-efficient computing and high-speed, high-capacity networks; ENG will work closely with OIA on the C-Accel planned for the area of HDR.

ENG's NNA Big Idea investments will help ensure sustainable and reliable infrastructure systems in the Arctic through research in, for example, sensor systems to understand soil dynamics, complex food-energy-water systems and models, water supply and treatment, resilient structure designs, and advanced materials.

To advance health technologies and systems, ENG will invest in fundamental research to observe nanoscale cellular processes and changes, in engineering biology to reverse disease and produce therapies, and in synthetic biology to support URoL, another NSF Big Idea. For more information about the Big Ideas, see the narratives in the NSF-Wide Investments chapter.

Along with its support for Big Ideas, ENG investments in artificial intelligence, quantum information sciences and technology, and microelectronics and semiconductor design and manufacturing will make essential contributions to U.S. competitiveness.

The directorate also will support neurotechnologies and imaging for UtB, including the BRAIN Initiative. Engineering investments will continue advances in prosthetic and assistive technologies for veterans and for aging and disabled people.

While fundamental engineering research fuels U.S. technological innovation and competitiveness, ENG support for workforce development and innovation speeds and strengthens the process. The directorate will invest in research on education, broadening participation, and inclusion in engineering, as well as in student experiences with industry. ENG will maintain its commitment to talented early-career faculty by making a sizable investment in CAREER and by allowing proposal submissions to core programs at any time to encourage creative, significant research contributions. ENG investments in academic partnerships with industry, entrepreneurial training through the I-Corps™ program, and small businesses through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs will help translate new ideas from lab to market and fortify the Nation's innovation ecosystem.

ENG provides 36 percent of the federal funding for basic research at academic institutions in the engineering disciplines.

Major Investments

ENG Major Investments
(Dollars in Millions)

				Change over FY 2018 Actual	
Area of Investment	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Amount	Percent
Advanced Manufacturing	$110.89	-	$110.89	-	-
Artificial Intelligence (AI)	114.70	-	126.45	11.75	10.2%
CAREER	78.56	-	76.00	-2.56	-3.3%
INFEWS	6.73	-	5.00	-1.73	-25.7%
IUSE	0.05	-	4.75	4.70	9465.6%
Microelectronics and Semiconductors	37.50	-	37.50	-	-
I-Corps™	17.20	-	15.40	-1.80	-10.4%
Quantum Information Sciences (QIS)	26.77	-	29.30	2.53	9.5%
SaTC	3.25	-	3.25	-	-
UtB	28.08	-	16.75	-11.33	-40.3%
BRAIN Initiative	*28.08*	*-*	*16.75*	*-11.33*	*-40.3%*
NSF's Big Ideas	-	-	30.00	30.00	N/A
FW-HTF Stewardship	-	-	*30.00*	*30.00*	*N/A*

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

- Advanced Manufacturing ($110.89 million) ENG research accelerates advances in manufacturing technologies with emphasis on multidisciplinary research that fundamentally alters and transforms manufacturing capabilities, methods and practices. Investments in advanced manufacturing include research on highly connected cyber-physical systems in smart processing and cyber manufacturing systems, and activities that develop new methods, processes, analyses, tools, or equipment for new or existing manufacturing products, supply chain components, or materials. NSF's investments will enable new functionalities that will increase the efficiency and sustainability of the production of the next generation of products and services. These developments will yield advantages such as reduced time to market, new performance attributes, improved small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

- AI ($126.45 million): ENG, together with other NSF directorates/offices, will increase support for AI research and development. A key focal point will be support for "AI Frontiers," a center-scale activity that will span (a) foundational areas of machine learning, computer vision, natural language processing, and autonomy, along with safety, security, robustness, and explainability of AI systems; (b) translational research at the intersection of AI and various science and engineering domains supported by NSF as well as sectors such as agriculture, advanced manufacturing, transportation, and personalized medicine; (c) workforce development, including growing human capital and institutional capacity to nurture a new generation of ethical AI researchers and practitioners; and (d) advanced computing infrastructure, including access to data and computing capabilities.

- Faculty Early Career Development (CAREER) ($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. This funding level will support approximately 150 awards.

- INFEWS ($5.0 million): ENG will continue to co-lead this NSF-wide initiative with GEO in FY 2020. 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 ($4.75 million): ENG's investment in the NSF-wide IUSE initiative, which integrates the agency's investments in undergraduate education, will continue as support for the IUSE/Professional Formation of Engineers: Revolutionizing Engineering 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.

- Microelectronics and Semiconductors ($37.50 million): ENG, together with other NSF directorates and offices, will support research to address fundamental science and engineering questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies. Research in semiconductors and microelectronics is critical to future advances and security in information technology, communications, sensing, smart electric grid, transportation, health, advanced manufacturing, and other areas. The investment will strengthen America's capabilities and capacity for revolutionary microelectronics design, architecture, and fabrication, as well as high-performance computing. New discoveries will enable the nation to overcome crucial scientific barriers for emerging technologies such as artificial intelligence, quantum technologies, and interconnected autonomous systems, and they will strengthen U.S. scientific leadership, economic prosperity, and national security.

- I-Corps™ ($15.40 million): ENG, in partnership with other directorates, will continue strong support for the NSF-wide 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.

- QIS ($29.30 million): ENG, together with other NSF directorates and offices, will increase support for quantum information science research and development, which strongly aligns with the Administration's National Quantum Initiative to consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts. Research in QIS examines uniquely quantum phenomena that can be harnessed to advance information processing, transmission, measurement, and fundamental understanding in ways that classical approaches can only do much less efficiently, or not at all. Current and future QIS applications differ from prior applications of quantum mechanics, such as the laser, transistor, and magnetic resonance imaging, by using distinct quantum phenomena—superposition and entanglement—that do not have classical counterparts. QIS research activities will also address education and workforce development needs, broadening research collaborations, promoting innovative team- building activities, and stimulating cross-disciplinary curriculum development and training to provide a quantum-smart workforce.

- SaTC ($3.25 million): ENG support for SaTC will focus on the engineering aspects of the NITRD Strategic Plan for the Federal Cybersecurity Research and Development Program.[1] NITRD's research thrusts cover a set of interrelated priorities for U.S. government agencies that conduct or sponsor research and development in cybersecurity.

- UtB ($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.

- FW-HTF ($30.0 million): ENG will steward the FW-HTF Big Idea. While financial stewardship for this Emerging Frontiers and Multidisciplinary Activities (EFMA) investment will be the responsibility of ENG, the convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. These activities will enable pursuit of fundamental research on advancing cognitive and physical capabilities in the context of human-technology interactions and the development of a 21st-century workforce capable of adapting to a changing employment landscape. ENG will work closely with OIA on the Convergence Accelerator (C-Accel) planned for the area of FW-HTF, building on collaborative design of the C-Accel model that draws on ENG experience in technology translation and partnerships.

[1] www.nitrd.gov/pubs/FY2019-Cybersecurity-RD-Roadmap.pdf

ENG Funding for Centers Programs and Facilities

ENG Funding for Centers Programs
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$83.42**	**-**	**$62.26**	**-$21.16**	**-25.4%**
Engineering Research Centers (EEC)	68.49	-	54.66	-13.83	-20.2%
STC: Emergent Behaviors for Integrated Cellular Systems (CBET)	5.00	-	1.30	-3.70	-74.0%
STC: Engineering Mechano-Biology (CMMI)	4.93	-	5.00	0.07	1.4%
STC: Energy Efficient Electronics Systems (ECCS)	5.00	-	1.30	-3.70	-74.0%

For detailed information about NSF Centers programs, please see the NSF-Wide Investments chapter.

ENG Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$26.37**	**-**	**$12.75**	**-$13.62**	**-51.6%**
Cornell High Energy Synchrotron Source (CHESS)	4.00	-	1.00	-3.00	-75.0%
Natural Hazards Engineering Research Infrastructure (NHERI)[1]	22.37	-	11.75	-10.62	-47.5%

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested

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

Funding Profile

ENG Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	13,092	-	10,000
Number of New Awards	2,458	-	2,200
Funding Rate	19%	N/A	22%
Statistics for Research Grants:			
Number of Research Grant Proposals	9,899	-	7,500
Number of Research Grants	1,844	-	1,680
Funding Rate	19%	N/A	22%
Median Annualized Award Size	$113,059	-	$114,000
Average Annualized Award Size	$131,793	-	$134,000
Average Award Duration, in years	2.7	-	2.8

ENG investments support fundamental engineering research, engineering education, and innovation, as well as research infrastructure such as facilities. In FY 2020, funding for centers accounts for over nine percent of ENG's non-SBIR/STTR Request. In FY 2020, funding for facilities is just under two percent of ENG's non-SBIR/STTR Request.

In FY 2020, the number of competitive proposals received, which includes SBIR/STTR proposals, is expected to be about 10,000, which includes about 7,500 research grant proposals. In FY 2019, ENG implemented the removal of all deadlines associated with unsolicited "core" programs across the directorate, which is expected to produce a reduction in the total number of proposals received and allow for increases in both award size and duration.

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- In FY 2015, NSF funded the National Academies of Sciences, Engineering, and Medicine (the National Academies) to study the future of center-based, multidisciplinary engineering research. The study report,[2] delivered May 2017, articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research. After careful consideration, in FY 2018 ENG sparked new convergence engineering research collaborations through planning grants, providing 60 awards to build capacity for a new generation of engineering research centers. In October 2018, ENG released a solicitation for the 4th generation of ERCs (NSF 19-503) and anticipates awards in 2020.
- Since 2016, the PFE:RED program has engaged a Participatory Action Research team (REDPAR) composed of two partners: the Center for Evaluation & Research in STEM Equity (CERSE) from the University of Washington and the Making Academic Change Happen (MACH) group from the Rose-Hulman Institute of Technology. REDPAR has collected data from a variety of sources for evaluation and assessment examining the partnerships that teams are creating along with the project results/outputs. The group has been providing feedback and briefings on a regular basis and will produce a summative report in the 2019–2020 timeframe. To date, ENG has used the data collected to change the language in RED solicitations to emphasize key areas that were not appropriately addressed in the proposals being received. For example, the FY 2019 solicitation includes a new track, the RED A&I (Adaptation and Implementation) track, that focuses on the use of evidence-based and evidence generating change strategy approaches and actions that are adapted to the local context of implementation.
- In FY 2016, NSF initiated a rigorous evaluation of the I-Corps™ Teams program. The evaluation seeks to assess the impact of the program on teams that completed the entrepreneurial training. In addition, NSF seeks to understand the impact of the program on academic culture, such as the kinds of networks and connections principal investigators develop with industry and investors and how their research and other activities are impacted by the I-Corps™ experience. The analysis relies on quantitative data from surveys and case studies developed from in-depth interviews and site visits. A report is expected to be available in FY 2019.
- In FY 2017, the American Innovation and Competitiveness Act (AICA) became law and required NSF to develop metrics to evaluate the I-Corps™ program and to deliver a report to Congress every two years. NSF has completed development of the metrics, prepared the first report, and plans to submit it to Congress in spring 2019.
- In FY 2018, the SBIR/STTR Baseline Monitoring Survey was cleared by the Office of Management and Budget. The survey consists of two parts: Company and Founder. The aim of the survey is to learn more about these small businesses shortly after they receive their first NSF SBIR/STTR Phase I awards. Some of the metrics collected in the survey include: technology readiness, R&D efforts, university affiliations, payroll and revenue, as well as NSF lineage. The survey allows ENG to create a performance baseline for these small businesses, benchmark internally across cohorts, understand what

[2] www.nap.edu/catalog/24767/a-new-vision-for-center-based-engineering-research

best-in-class small businesses do differently, and identify root causes for low performers so NSF can design tailored improvement initiatives for the SBIR and STTR programs. ENG is administering surveys to small businesses who received their Phase I award in 2018 and 2019.

- In FY 2019, the data collection and management process for the Industry-University Cooperative Research Center (IUCRC) program is migrating from North Carolina State University to NSF. One of the overarching goals of this migration process involves building an in-house data ecosystem for the IUCRC program that entails collecting, organizing, and managing internal and external data, including data from an annual survey. The combination of data sources will provide a holistic view of the IUCRC program and enable customized analyses and insights to be made on a center level.

Workshops and Reports:

- In FY 2016, CBET, EFMA and others co-funded a three-year study on Grand Challenges in Environmental Engineering by the National Academies.[3] The study aimed to identify high-priority challenges for environmental engineering and science for the next several decades. The three planned public workshops associated with the study were held May 2017; September 2017; and January 2018. The report,[4] delivered in December 2018 at a 500-person event, 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. In addition, the Association of Environmental Engineering and Science Professors (AEESP) will convene a special session during their 2019 biannual meeting on the Grand Challenges for Engineering.
- With ECCS support, a workshop on Microsystems for Bioelectronics Medicine organized by NSF and the Semiconductor Research Corp. (SRC) was held in April 2017. The organizing committee included extensive representation from other federal agencies (Defense Advanced Research Projects Agency, Department of the Army, Food and Drug Administration, the National Institutes of Health [NIH]) and pharmaceutical and other companies (such as Medtronic, Boston Scientific, Philips, Intel, GlaxoSmithKline, Pfizer, IBM, and Texas Instruments). The workshop helped identify scientific areas for future investment in ECCS core programs and led to an NSF-SRC-IARPA solicitation on Semiconductor Synthetic Biology for Information Processing and Storage Technologies (SemiSynBio) (NSF 17-557),[5] with awards in FY 2018.
- In FY 2017, ENG (CBET and EFMA) and BIO co-funded a workshop on "The Subterranean Macroscope: Sensor networks for understanding, modeling, and managing soil processes," held November 2017, at the University of Chicago. The workshop's goal was to create a vision and framework for how such a subterranean sensor network could be built across different geographical scales, with sensors that will generate dense, useful data that will inform soil science, plant science, and modeling efforts. These efforts, in turn, would lead to the next level of understanding of the physical, chemical, and biological nature of soil and its impact on plant science and food security. The workshop included diverse scientists and engineers and representatives from industry and the small business community. The workshop was expected to generate cross-directorate research opportunities advancing measurement system capabilities for soil biological, chemical, and physical components over space and time and to contribute to several of NSF's 10 Big Ideas. The workshop led to the multi-directorate NSF Dear Colleague Letter on Signals in the Soil (NSF 18-047)[6] in FY 2018 and the NSF solicitation on Signals in the Soil (NSF 19-556)[7] in FY 2019; collaborating with NSF in FY 2019 are the U.S. Department of Agriculture's National Institute of Food and Agriculture (USDA/NIFA) and several

[3] http://dels.nas.edu/Study-In-Progress/Grand-Challenges-Opportunities-Environmental/DELS-WSTB-15-01
[4] www.nap.edu/catalog/25121/environmental-engineering-for-the-21st-century-addressing-grand-challenges
[5] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505397
[6] www.nsf.gov/pubs/2018/nsf18047/nsf18047.jsp
[7] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505577&org=NSF

arms of the United Kingdom's Research and Innovation.

- In FY 2017, CMMI supported a workshop on "Disrupting Illicit Supply Networks: New Applications of Operations Research and Data Analytics to End Modern Slavery,"[8] in December 2017. The workshop brought together operations researchers, computer scientists, social scientists, business researchers, geographers, social service agency representatives, and federal agencies to increase understanding of both the nature, and the challenges to disruption, of illicit supply chains. This led to a dear colleague letter[9] from the CMMI Operations Engineering program for an initial round of awards[10] in FY 2018; a follow-up workshop is planned for March 2019.
- ECCS sponsored a workshop on Real-time Learning and Decision Making in Dynamical systems in February 2018.This workshop brought together a group of 130 leading experts in complementary backgrounds to bridge research areas and shape the research paradigm that arises from many real-time data-driven dynamical systems. This workshop looked at ways to integrate data science methods with domain knowledge from physical engineering systems to make critical decisions in real-time. The workshop led to the ENG Dear Colleague Letter: Real-Time Learning and Decision-Making in Engineered Systems (Real-D) (NSF18-063)[11] that funded about $5.0 million in NSF EArly Concepts for Exploratory Research (EAGER) grants in real-time learning and decision making applied to engineering systems. The outcomes of this workshop strongly impacted current funding activities under the HDR Big Idea.
- In FY 2018, CBET and National Aeronautics and Space Administration's (NASA) Ames Research Center and Centennial Challenges program co-funded a Bioengineering Road Map Summit[12] held March 2018. At the Summit, 110 academics, industry professionals, and government leaders came together to identify, characterize, and review specific scientific and technical hurdles toward creating bioengineered solutions to ending the organ shortage. The outcomes included a comprehensive version of the "Road Map to Ending the Organ Shortage" for use by the research community and public alike. 3D tissue and organ engineering has been identified as a high priority area of research by the federal government, and major initiatives are underway through NSF, NIH, Department of Defense, and the U.S. Department of Veterans Affairs (VA). This Summit has helped coordinate efforts between all active partners, including industry and academia, which is required to move science and engineering from academic laboratory to clinical translation in the most effective way possible.
- In FY 2019, an ECCS-supported workshop on Power Electronics in the Electrified Transportation Industry was held in October 2018. Power electronics play a critical role in efficient and reliable electric propulsion, fast and dynamic wireless charging, active suspension, energy harvesting, electrically assisted steering, and anti-lock-braking systems. The workshop brought together researchers and technical leaders from academia and industry to discuss scientific/technological breakthroughs that are needed in this emerging field. The report from this workshop, which will be available in fall 2019, will inform ECCS plans and priorities in the area of smart electric grid.
- With support from ECCS and MPS/Division of Materials Research, the Optical Society of America organized an incubator workshop on Quantum Nanophotonics in Emerging Materials[13] in October 2018, to help establish new directions for research with optically-active semiconductor defects that take advantage of the unique properties afforded by emerging materials. The workshop brought together three different related but often non-intersecting communities to discuss how to advance materials, theory, and instrumentation to realize new quantum-coherent systems with unprecedented functionality. The report will be available in 2019. The results will inform future activities under the

[8] http://ic2.utexas.edu/disn2017/
[9] www.nsf.gov/pubs/2018/nsf18059/nsf18059.jsp
[10] nsf.gov/news/news_summ.jsp?cntn_id=296258
[11] www.nsf.gov/pubs/2018/nsf18063/nsf18063.jsp
[12] www.neworgan.org/roadmap-summit.php
[13] www.osa.org/en-us/meetings/incubator_meetings/past_incubator_meetings/2018/osa_defects_by_design_incubator_quantum_nanophoto/

QL Big Idea.

- In FY 2019, CMMI supported an award for the planned "International Workshop on Bio-Inspired Geotechnics,"[14] to be held in May 2019. The emerging field of bio-inspired geotechnics is at a critical, formative stage where researchers are beginning to define how biological phenomena can inspire an engineering analog in geotechnical applications such as earthworks, foundations, or pavements to support built structures. This workshop, with 55 interdisciplinary individuals from across the world, will accelerate growth in this new field and inform the creation of a potential research initiative supporting bio-inspired engineering and design.

Committees of Visitors (COV):

- In 2018, COVs reviewed ECCS and EFMA for the period FY 2014–2017. The COVs presented their reports to the ENG Advisory Committee, which convened in April and October of 2018. The ECCS COV recommended that the division return to multiple submission windows, and ECCS, along with CBET, CMMI, and EEC, instituted a new policy beginning in FY 2019 that removes deadlines for submission of unsolicited proposals to all core programs. The EFMA COV recommended that EFMA encourage individuals performing proposal review to provide some level of detail for all review requirements, and in FY 2018, EFMA began providing templates for both reviews and panel summaries that list each criterion for specific comment.
- In 2019, COVs will review CBET and CMMI.
- In 2020, COVs will review EEC and IIP.

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.

People Involved in ENG Activities

Number of People Involved in ENG Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	9,299	-	8,900
Other Professionals	1,937	-	1,900
Postdoctoral Associates	484	-	500
Graduate Students	7,760	-	7,200
Undergraduate Students	4,217	-	4,200
Total Number of People	**23,697**	-	**22,700**

[14] sites.google.com/view/1st-bio-geotech-workshop

DIVISION OF CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, AND TRANSPORT SYSTEMS (CBET) **$169,430,000**
-$17,760,000 / -9.5%

CBET Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$187.19**	**-**	**$169.43**	**-$17.76**	**-9.5%**
Research	**181.57**	**-**	**163.64**	**-17.93**	**-9.9%**
CAREER	31.72	-	31.00	-0.72	-2.3%
Centers Funding (total)	5.00	-	1.30	-3.70	-74.0%
STC: Emergent Behaviors for Integrated Cellular Systems	5.00	-	1.30	-3.70	-74.0%
Education	**1.91**	**-**	**2.10**	**0.19**	**9.9%**
Infrastructure	**3.71**	**-**	**3.69**	**-0.02**	**-0.5%**
NNCI	3.68	-	3.69	0.01	0.3%

About CBET

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, about 84 percent of the CBET portfolio is available to support new research grants. The remaining 16 percent supports research grants made in prior years and the research infrastructure needed by this community.

DIVISION OF CIVIL, MECHANICAL, AND MANUFACTURING INNOVATION (CMMI) — $204,000,000 / -$32,950,000 / -13.9%

CMMI Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$236.95**	**-**	**$204.00**	**-$32.95**	**-13.9%**
Research	**210.02**	**-**	**186.90**	**-23.12**	**-11.0%**
CAREER	32.24	-	30.00	-2.24	-6.9%
Centers Funding (total)	4.93	-	5.00	0.07	1.4%
STC: Engineering Mechano-Biology	4.93	-	5.00	0.07	1.4%
Education	**2.67**	**-**	**2.65**	**-0.02**	**-0.7%**
Infrastructure	**24.27**	**-**	**14.45**	**-9.82**	**-40.5%**
CHESS	-	-	0.80	0.80	N/A
NHERI[1]	22.37	-	11.75	-10.62	-47.5%
NNCI	1.90	-	1.90	-	-

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested amount.

About CMMI

CMMI funds fundamental research in support of the Foundation’s strategic goals directed at advances in 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 cross-cutting technologies such as adaptive systems, artificial intelligence, 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 (such as semiconductor fabrication); 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.

CMMI also provides funding and management of NHERI and contributes to the directorate’s annual operations support of the CHESS facility.

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

DIVISION OF ELECTRICAL, COMMUNICATIONS, AND CYBER SYSTEMS (ECCS) **$105,040,000**
-$11,010,000 / -9.5%

ECCS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$116.05**	**-**	**$105.04**	**-$11.01**	**-9.5%**
Research	**109.99**	**-**	**98.04**	**-11.95**	**-10.9%**
CAREER	13.55	-	15.00	1.45	10.7%
Centers Funding (total)	5.00	-	1.30	-3.70	-74.0%
STC: Energy Efficient Electronics	5.00	-	1.30	-3.70	-74.0%
Education	**0.68**	**-**	**1.66**	**0.98**	**143.4%**
Infrastructure	**5.37**	**-**	**5.34**	**-0.03**	**-0.6%**
CHESS	-	-	0.10	0.10	N/A
NNCI	5.37	-	5.24	-0.13	-2.5%

About ECCS

ECCS supports enabling and transformative research at the nano, micro, and macro scales that fuels progress in engineering system applications with high societal impacts. The division's programs encompass novel electronic, photonic, quantum, and magnetic devices (such as semiconductors integrated with biological structures), and the integration of these devices into circuit and system environments, intelligent systems, control, and networks. ECCS investments in artificial intelligence research for real-time learning and decision-making will lead to safe, reliable, and efficient data-enabled engineering systems. Breakthroughs in devices and systems advance applications spanning communications and cyber technologies, energy and power, healthcare, environment, transportation, robotics, manufacturing, and other systems-related areas. ECCS strongly emphasizes the integration of education into its research programs to ensure the preparation of a diverse and professionally skilled workforce. ECCS also strengthens its programs through links to other areas of engineering, science, industry, government, and international collaborations.

The division also provides funding, in partnership with other NSF directorates, and management of the National Nanotechnology Coordinated Infrastructure (NNCI).

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

DIVISION OF ENGINEERING EDUCATION AND CENTERS (EEC) **$92,600,000**
-$24,110,000 / -20.7%

EEC Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$116.71**	**-**	**$92.60**	**-$24.11**	**-20.7%**
Research	**93.79**	**-**	**76.49**	**-17.30**	**-18.4%**
CAREER	0.77	-	-	-0.77	-100.0%
Centers Funding (total)	68.49	-	54.66	-13.83	-20.2%
Engineering Research Centers	68.49	-	54.66	-13.83	-20.2%
Education	**22.93**	**-**	**16.11**	**-6.82**	**-29.7%**

About EEC

EEC integrates disciplinary basic research and education conducted in other ENG divisions and across NSF into strategic frameworks that address societal grand challenges and promote 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. Creative and effective 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 also defining 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. The Major Centers and Facilities category is comprised of the signature Engineering Research Centers (ERC) program.

The ERC program provides the framework for interdisciplinary research and education, development, and technology transfer in partnership with academia, industry, and government. The FY 2020 funding level supports 17 centers. The total includes initial funding for three 4th-generation ERCs that will advance convergence engineering research to tackle high-impact challenges and benefit U.S. security, prosperity, health and society. The new ERCs will implement new strategies for effective team formation and engagement with stakeholder communities to maximize their impacts. As referenced in the Program Monitoring and Evaluation section, in FY 2015, NSF funded the National Academies to study the future of center-based, multidisciplinary engineering research. The study report articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research. After careful consideration, in FY 2018 ENG sparked new convergence engineering research collaborations through planning grants, providing 60 awards to build capacity for a new generation of engineering research centers. In October

2018, ENG released a solicitation (NSF 19-503) for the 4th generation of ERCs and anticipates awards in 2020.

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 Workforce Development includes programs such as Research Experiences for Undergraduate (REU) and Research Experiences for Teachers. 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 Big Idea, 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.

DIVISION OF INDUSTRIAL INNOVATION AND PARTNERSHIPS (IIP) **$245,250,000**
-$26,460,000 / -9.7%

IIP Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$271.71**	**-**	**$245.25**	**-$26.46**	**-9.7%**
Research	**271.52**	**-**	**244.86**	**-26.66**	**-9.8%**
SBIR/STTR, including Operations	209.98	-	195.15	-14.83	-7.1%
SBIR	182.39	-	166.71	-15.68	-8.6%
STTR	22.59	-	23.44	0.85	3.8%
SBIR/STTR Operations	5.00	-	5.00	-	-
Education	**0.20**	**-**	**0.39**	**0.19**	**97.2%**

About IIP

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 hi-tech entrepreneurs and innovators.

IIP is home to two cross-agency small business research programs, the SBIR and STTR programs. These programs seek to transform scientific discovery into societal and economic benefit by catalyzing private sector commercialization of technological innovations. SBIR/STTR programs provide the opportunity for startups and small businesses to undertake cutting-edge, high-quality scientific research and development to determine the scientific and technical feasibility of a new concept or innovation that could be developed into 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 industry-university research programs: IUCRC, Partnerships for Innovation (PFI), and Grant Opportunities for Academic Liaison with Industry (GOALI)/Non-Academic Research Internships for Graduate Students (INTERN). 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 three percent supports continuing grants.

OFFICE OF EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES (EFMA) $65,100,000 +$15,820,000 / 32.1%

EFMA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$49.28**	**-**	**$65.10**	**$15.82**	**32.1%**
Research	**41.22**	**-**	**64.90**	**23.68**	**57.5%**
Big Idea: FW-HTF	-	-	30.00	30.00	N/A
Education	**4.07**	**-**	**0.10**	**-3.97**	**-97.5%**
Infrastructure	**4.00**	**-**	**0.10**	**-3.90**	**-97.5%**
CHESS	4.00	-	0.10	-3.90	-97.5%

About EFMA

EFMA strategically pursues and supports projects in important emerging areas. The office also provides support to high impact multidisciplinary education and learning platform programs such as Germination of Research Ideas for Large Opportunities and Critical Societal Needs (GERMINATION), Research Experience and Mentoring (REM), REU supplements, and contributes to the directorate's annual operations support of NSF facilities such as CHESS.

Funding for the FW-HTF Big Idea ($30.0 million) will support convergence activities that transcend the traditional disciplinary boundaries of individual NSF directorates and offices. While financial stewardship for this NSF investment will be the responsibility of ENG, the convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. These activities will enable pursuit of fundamental research on advancing cognitive and physical capabilities in the context of human-technology interactions, and the development of a 21st-century workforce capable of adapting to a changing employment landscape.

A major activity in EFMA is the Emerging Frontiers in Research and Innovation (EFRI) program. Each year EFRI funds interdisciplinary projects at the frontiers of engineering that have the potential for major impacts on national needs and/or grand challenges, particularly in areas that may lead to breakthrough technologies and strengthen the economy's technical underpinnings. Recent EFRI topics have included areas such as: integrated processes and systems designed to make U.S. infrastructures more resilient; highly secure communication using advanced quantum technologies; advances in soft robotics; flexible technologies and regenerative engineering for healthcare; and biomolecular engineering technologies that will lead to transformative strategies for the screening and treatment of pre-cancers, to solve persistent environmental problems, and uncover new plant traits for agriculture. 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.

During FY 2016–2017, EFRI invested in Advancing Communication Quantum Information Research in Engineering (ACQUIRE) that 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. In FY 2018 and FY 2019, EFRI is investing in two new topics: Chromatin and Epigenetic Engineering (CEE) and Continuum, Compliant, and Configurable Soft Robotics Engineering (C3 SoRo). EFRI is collaborating with BIO, CISE, and MPS and the Air Force Office of Scientific Research

(AFOSR) on these topics. A competition is currently underway for selection and prioritization of EFRI topic areas for FY 2020 and FY 2021 based on ideas submitted by the research community.

In general, about 76 percent of the EFMA portfolio is comprised of new research grants, and about 24 percent supports continuing increments for grants made in previous years.

DIRECTORATE FOR GEOSCIENCES (GEO) **$787,050,000**
-$120,750,000 / -13.3%

GEO Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Division of Atmospheric and Geospace Sciences (AGS)	$276.10	-	$221.97	-$54.13	-19.6%
Division of Earth Sciences (EAR)	179.69	-	156.97	-22.72	-12.6%
Integrative and Collaborative Education & Research (ICER)	85.75	-	93.20	7.45	8.7%
Division of Ocean Sciences (OCE)	366.26	-	314.91	-51.35	-14.0%
Total	**$907.80**	**-**	**$787.05**	**-$120.75**	**-13.3%**

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 create and sustain vital natural resources on which society depends. Our mineral, energy, and water resources result from diverse Earth processes including the planet's water cycle, interactions across the land-ocean interface, the behavior of ice sheets, and geologic processes responsible for hydrocarbon energy sources and strategic minerals. Basic research supported by GEO contributes to the understanding of these processes and the resources that result from them. In addition, lives are saved and property is preserved by better forecasting and understanding of natural environmental hazards such as earthquakes, tornadoes, drought, and solar storms. GEO-supported research improves society's preparation for the effects of these and other disruptive natural events, and GEO prioritizes support 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.

Leveraging the knowledge and techniques of many other disciplines, GEO strongly promotes the growth of convergence research across all fields of science. GEO activities support and promote many of NSF's Big Ideas. OPP within GEO, in coordination with ENG and SBE, manages NSF's NNA Big Idea, with $30.0 million in the ICER division held in stewardship to support crosscutting NNA research. GEO programs also contribute to HDR through the EarthCube activity. As observational sciences, geosciences rely on vast archives of data to forge new knowledge about the Earth. GEO also participates in URoL, primarily with focuses on microbiomes in the aquatic realm.

In addition, OPP operates as part of GEO; more information on OPP can be found in the OPP narrative in this chapter.

GEO provides about 58 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
INFEWS	$7.00	-	$8.00	$1.00	14.3%
IUSE	5.82	-	5.70	-0.12	-2.0%
I-Corps™	0.60	-	0.60	-	-
NSF's Big Ideas					
NNA Stewardship	-	-	*30.00*	*30.00*	*N/A*

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

- INFEWS ($8.0 million): In FY 2020, NSF is continuing to build and support an interdisciplinary investment to study the food-energy-water nexus through INFEWS to enable accelerated research of this nexus.

- IUSE ($5.70 million): Funding for the NSF-wide IUSE activity continues to support development of the next generation of geoscientists.

GEO Funding for Centers Programs and Facilities

GEO Funding for Centers Programs
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$5.00**	**-**	**$1.30**	**-$3.70**	**-74.0%**
STC: Center for Dark Energy Biosphere Investigations (OCE)	5.00	-	1.30	-3.70	-74.0%

For detailed information about NSF Centers programs, please see the NSF-Wide Investments chapter.

GEO Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$344.53**	**-**	**$293.53**	**-$51.00**	**-14.8%**
Academic Research Fleet (ARF)	86.03	-	74.10	-11.93	-13.9%
Arecibo Observatory	5.42	-	2.13	-3.29	-60.7%
Geodetic Facility for the Advancement of GEoscience (GAGE)	11.49	-	11.86	0.37	3.2%
International Ocean Discovery Program (IODP)	47.55	-	45.80	-1.75	-3.7%
National Center for Atmospheric Research (NCAR)	126.34	-	99.70	-26.64	-21.1%
Ocean Observatories Initiative (OOI)	44.08	-	38.00	-6.08	-13.8%
Seismological Facility for the Advancement of GEoscience (SAGE)	23.61	-	21.94	-1.67	-7.1%

[1] In FY 2018, Congress appropriated additional funding to NSF above the Request level, which was in part allocated to several facilities for one time enhancements, forward funding of future activities, and/or development and design.

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

Funding Profile

GEO Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	3,222	-	3,300
Number of New Awards	1,201	-	1,050
Funding Rate	37%	N/A	32%
Statistics for Research Grants:			
Number of Research Grant Proposals	2,853	-	2,900
Number of Research Grants	990	-	850
Funding Rate	35%	N/A	29%
Median Annualized Award Size	$162,948	-	$163,000
Average Annualized Award Size	$215,234	-	$215,000
Average Award Duration, in years	2.9	-	3.0

As NSF’s Big Ideas ramp up, a net increase in incoming proposals is expected, which will likely result in a net reduction in overall funding rates in GEO.

Program Monitoring and Evaluation

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

- In FY 2018, EAR funded a three-year study on Catalyzing Opportunities for Research in Earth Sciences by the National Academies of Science, Engineering, and Medicine (the National Academies). This study will identify high research priorities for the division. The first public meeting took place in November 2018.
- The Science, Engineering, and Education for Sustainability (SEES) program, which ended in FY 2017, was assessed, with the final report delivered in FY 2018. The evaluation under sponsorship of GEO

and OIA included the following tasks: (1) examining the effectiveness of SEES, (2) completing a historical review of NSF's sustainability efforts in the past 15 years, and (3) reviewing the SEES portfolio solicitations from 2010 to 2014. The contractor's analyses produced interesting findings, including:

- Collaboration intensity of SEES teams is higher than that of non-SEES teams for collaborations within the research community, and the difference is statistically significant. This suggests that the SEES funding mechanism was particularly effective in creating dynamic networks of interdisciplinary collaborators as measured by the density of ties among experts on all NSF awards won during the full study period. Overall, the SEES funding mechanism was more successful than the non-SEES funding mechanism in attracting investigators from a different discipline. The larger team sizes supported by the SEES funding mechanism seemed to create more opportunity for the inclusion of social scientists and education researchers.
- SEES awards enriched the quality of education in science across all levels—from kindergartners to senior citizens—through a myriad of events for students, totaling over 453 educational-focused products or activities across the country and internationally, including lab tours, science fairs, and the promotion of careers in science. SEES principal investigators (PIs) have published in a large number of multidisciplinary journals. They raised the visibility of and interest in sustainability research as implied by the high citation counts of their publications.

<u>Workshops and Reports:</u>

- The OCE is sponsoring a facilitated workshop in FY 2019 titled "Future of Marine Seismic Capabilities Workshop" to address plans for 3-Dimensional and deep crustal seismic data acquisition for NSF-funded basic research in the marine geosciences after retirement of the NSF-owned Research Vessel *Marcus G. Langseth* in late calendar 2020.

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

- In 2018, COVs reviewed Geospace programs in the AGS and the Integrative Programs Section in OCE. The COV reports were presented to the GEO Advisory Committee at their October 2018 meeting. In its report, the COV looking at geospace programs recommended that programs consider sustainability of early career researchers, and recommended that a future COV examine the long-term effectiveness of supporting CubeSats.
- In 2019, COVs will review facilities and infrastructure in AGS and research programs in OCE.
- In 2020, a COV will review lower atmospheric research, infrastructure, and education programs in AGS.

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

People Involved in GEO Activities

Number of People Involved in GEO Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	4,615	-	4,000
Other Professionals	2,758	-	2,400
Postdoctoral Associates	602	-	500
Graduate Students	2,178	-	1,900
Undergraduate Students	2,110	-	1,800
Total Number of People	**12,263**	**-**	**10,600**

DIVISION OF ATMOSPHERIC AND GEOSPACE SCIENCES (AGS)

$221,970,000
-$54,130,000 / -19.6%

AGS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$276.10**	**-**	**$221.97**	**-$54.13**	**-19.6%**
Research	**116.01**	**-**	**96.00**	**-20.01**	**-17.2%**
CAREER	8.09	-	4.00	-4.09	-50.5%
Education	**2.91**	**-**	**3.64**	**0.73**	**24.9%**
Infrastructure	**157.18**	**-**	**122.33**	**-34.85**	**-22.2%**
Arctic Logistics	0.78	-	-	-0.78	-100.0%
Arecibo Observatory	5.42	-	2.13	-3.29	-60.7%
NCAR[1]	126.34	-	99.70	-26.64	-21.1%
Research Resources	24.64	-	20.50	-4.14	-16.8%

[1] FY 2018 Actual includes $26.64 million in additional FY 2018 one-time funding above the requested amount.

About AGS

AGS supports fundamental research activities that lead to improved 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. Improved understanding drives state-of-the-science model development and improved predictability of weather, climate, and space weather events. 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. AGS support occurs via the traditional individual investigator merit-reviewed multi-year grants, limited duration exploratory research projects, and collaborative and multi-investigator group projects. In addition, research is conducted using leadership-class facilities provided by the National Center for Atmospheric Research (NCAR). Through improvements to our understanding of severe weather events, and the development of sophisticated computer models that simulate and forecast such events and their impacts, AGS helps protect life, property, and natural resources, and contributes to the establishment of a weather-ready and space weather-ready nation. AGS-supported scientists lead innovations ranging from the miniaturization of sensors that fly on cubesats, to the creation of high-resolution models that enable prediction of a variety of severe weather hazards. AGS also funds STEM education, fosters the success of early career scientists, and supports the continuing development of a world-class scientific and technical workforce that contributes significantly to the nation's economic vitality.

About 27 percent of the AGS portfolio is available for 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. AGS frequently participates in major NSF-wide initiatives and long-standing NSF programs, such as the Major Research Instrumentation program. AGS also partners with other programs within GEO, across other NSF directorates, and with other federal agency partners, to help ensure that the most impactful science is being funded.

DIVISION OF EARTH SCIENCES (EAR) $156,970,000
-$22,720,000 / -12.6%

EAR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$179.69**	**-**	**$156.97**	**-$22.72**	**-12.6%**
Research	**117.69**	**-**	**100.36**	**-17.33**	**-14.7%**
CAREER	9.34	-	5.99	-3.35	-35.9%
Education	**4.97**	**-**	**4.51**	**-0.46**	**-9.2%**
Infrastructure	**57.03**	**-**	**52.10**	**-4.93**	**-8.6%**
Geodetic Facility for the Advancement of GEoscience (GAGE)	11.49	-	11.86	0.37	3.2%
National Nanotechnology Coordinated Infrastructure (NNCI)	0.30	-	0.30	-	-
Seismological Facility for the Advancement of GEoscience (SAGE)	23.61	-	21.94	-1.67	-7.1%
Research Resources	21.63	-	18.00	-3.63	-16.8%

About EAR

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, petrology and geochemistry, tectonics, 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; and an education program that funds several activities to attract and support students and young investigators to the field of Earth science.

In general, about 40 percent of the EAR portfolio is available for new research grants. The remaining 60 percent supports research grants made in prior years and the research infrastructure needed by this community.

DIVISION OF INTEGRATIVE AND COLLABORATIVE EDUCATION & RESEARCH (ICER) **$93,200,000**
+$7,450,000 / 8.7%

ICER Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual: Amount	Change over FY 2018 Actual: Percent
Total	**$85.75**	**-**	**$93.20**	**$7.45**	**8.7%**
Research	**70.40**	**-**	**87.50**	**17.10**	**24.3%**
Big Idea: NNA	**-**	**-**	30.00	30.00	N/A
CAREER	0.40	-	-	-0.40	-100.0%
Education	**15.35**	**-**	**5.70**	**-9.65**	**-62.9%**

About ICER

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 join with other parts of NSF in major integrative research and education efforts. In addition, in partnership with several of the NSF directorates, ICER will advance the NNA Big Idea by investing funds to support convergent activities that transcend the traditional disciplinary boundaries of individual NSF directorates and offices. In FY 2020, 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. In 2019 several education programs were consolidated into other parts of NSF, which is reflected in the reduction in ICER education support.

In general, about 50 percent of the ICER portfolio is available for new research grants with the remaining amount supporting grants made in prior years.

DIVISION OF OCEAN SCIENCES (OCE) **$314,910,000**
-$51,350,000 / -14.0%

OCE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$366.26**	**-**	**$314.91**	**-$51.35**	**-14.0%**
Research	**168.29**	**-**	**143.37**	**-24.92**	**-14.8%**
CAREER	3.94	-	2.00	-1.94	-49.3%
Centers Funding (total)	5.00	-	1.30	-3.70	-74.0%
STC: Center for Dark Energy Biosphere Investigations	5.00	-	1.30	-3.70	-74.0%
Education	**4.93**	**-**	**4.84**	**-0.09**	**-1.8%**
Infrastructure	**193.05**	**-**	**166.70**	**-26.35**	**-13.6%**
Academic Research Fleet[1]	86.03	-	74.10	-11.93	-13.9%
Antarctic Facilities & Operations	3.66	-	-	-3.66	-100.0%
International Ocean Discovery Program	47.55	-	45.80	-1.75	-3.7%
Ocean Observatories Initiative	44.08	-	38.00	-6.08	-13.8%
Research Resources	11.72	-	8.80	-2.92	-24.9%

[1] FY 2018 Actual includes $6.0 million in additional FY 2018 one-time funding above the requested amount.

About OCE

OCE supports interdisciplinary research, education, and cutting-edge infrastructure that advances our scientific knowledge of the oceans to support the U.S. economy over the long term, provides vital information regarding national security matters such as sea level rise, and advances U.S. leadership in ocean science and technological innovation. OCE provides support of basic scientific research and technology development to better understand changing ocean circulation and other physical parameters, biodiversity and the dynamics of marine organisms and ecosystems, and changing ocean chemistry as exemplified by ocean acidification. OCE also supports research on the geology of the ocean margins and sub-seafloor to investigate the occurrence of methane hydrates, natural hazards associated with earthquakes and volcanic eruptions, microbial life deep below the seafloor, and other fundamental ocean processes. Ocean education emphasizes the interdisciplinary nature of ocean sciences, and commonly leverages research facilities and infrastructure via telepresence to far and distant seas. Since ocean science requires access to the sea, OCE supports research vessels, deep submergence capability including submersibles and autonomous vehicles, and technologically-advanced sensors and instrumentation. Broadly speaking, research, education, and infrastructure funded by OCE addresses the central role of the oceans in a changing Earth and as a national strategic resource, as recognized by numerous reviews by external bodies (e.g., the National Academies Decadal Survey *Sea Change*).

In general, about 34 percent of the OCE portfolio is available for new research grants, with the remainder supporting grants made in prior years and the research infrastructure needed by this community.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS) — $1,255,820,000 / -$247,590,000 / -16.5%

MPS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Astronomical Sciences (AST)	$311.16	-	$217.08	-$94.08	-30.2%
Chemistry (CHE)	246.29	-	214.18	-32.11	-13.0%
Materials Research (DMR)	337.14	-	273.78	-63.36	-18.8%
Mathematical Sciences (DMS)	237.69	-	203.26	-34.43	-14.5%
Physics (PHY)	310.75	-	247.50	-63.25	-20.4%
Office of Multidisciplinary Activities (OMA)	60.39	-	100.02	39.63	65.6%
Total	**$1,503.41**	**-**	**$1,255.82**	**-$247.59**	**-16.5%**

About MPS

The MPS FY 2020 Request builds on past efforts and aligns with NSF priorities for FY 2020. The programs in MPS span from individual investigator awards to large, multi-user facilities. MPS-funded 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 most awards, but centers, institutes, and facilities are all integral to MPS-funded research.

The MPS FY 2020 Request is influenced by four key priorities: (1) sustaining core research programs, (2) supporting the highest priority facilities, (3) supporting early-career investigators, and (4) providing funding for targeted basic research in NSF-Wide Investments, including the NSF Big Ideas.

MPS continues to support its core areas of science (astronomical sciences, chemistry, materials research, mathematical sciences, and physics) as well as thet next generation of scientists. Early-career investigators continue to be a priority, and are supported via the CAREER program, MPS core programs, and by crosscutting programs in which MPS participates.

MPS is the steward of funds designated for NSF Big Ideas: QL and WoU. These convergent activities will enable pursuit of fundamental research in quantum-enabled sciences and technologies and multi-messenger astrophysics. By exploiting quantum phenomena such as superposition, entanglement, and squeezing, the QL activities will develop the foundations for and enable quantum computing, quantum sensors, quantum communications, quantum simulators, and other inherently quantum technologies. In addition, these activities will contribute to the development of the nation’s workforce in quantum information sciences. The WoU activities will bring together fundamental research in electromagnetic waves, high-energy particles, and gravitational waves; advance the study of the universe; and grow the Nation’s multi-messenger astrophysics, engineering, and data science workforce. For more information about the NSF Big Ideas, see the NSF-Wide Investments chapter.

MPS provides approximately 50 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Advanced Manufacturing	$112.37	-	$112.37	-	-
Artificial Intelligence (AI)	25.51	-	32.33	6.82	26.7%
CAREER	82.86	-	68.39	-14.47	-17.5%
I-Corps™	1.70	-	1.70	-	-
Microelectronics and Semiconductors	13.40	-	13.40	-	-
Quantum Information Sciences (QIS)	56.65	-	58.12	1.47	2.6%
SaTC	1.49	-	1.00	-0.49	-32.9%
UtB	22.02	-	11.80	-10.22	-46.4%
BRAIN Initiative	*22.02*	*-*	*11.80*	*-10.22*	*-46.4%*
NSF's Big Ideas					
QL Stewardship	-	-	*30.00*	*30.00*	*N/A*
WoU Stewardship	-	-	*30.00*	*30.00*	*N/A*

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

- Advanced Manufacturing: In FY 2020, MPS will focus advanced manufacturing investments on activities that develop new methods, processes, analyses, tools or equipment for new or existing manufacturing products, supply chain components, or materials. These developments will yield advantages such as reduced time to market, new performance attributes, improved small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

- AI: MPS, together with other NSF directorates/offices, will increase support for artificial intelligence research and development. A key focus will be on supporting basic research in machine learning and deep learning.

- CAREER: Supporting the next generation of researchers remains a priority for MPS, and the CAREER Program continues to be a mechanism for recognizing the most innovative early career investigators. MPS anticipates approximately 130-150 CAREER awards.

- I-Corps™: Together with other NSF directorates and offices, MPS will support this program which 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.

- Microelectronics and Semiconductors: MPS, together with other NSF directorates/offices, will continue to support research to address fundamental science questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies, with a focus on materials. Research in semiconductors and microelectronics is critical to future advances and security in information technology, communications, sensing, smart electric grid, transportation, health, advanced manufacturing, and other areas. The investment will strengthen America’s capabilities and capacity for revolutionary microelectronics design, architecture, and fabrication, as well as high-performance computing.

- QIS: MPS, together with other NSF directorates/offices, will increase support for quantum information science research and development, which strongly aligns with the Administration's National Quantum Initiative to consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts. Research in QIS examines uniquely quantum phenomena that can be harnessed to advance information processing, transmission, measurement, and fundamental understanding in ways that classical approaches can only do much less efficiently, or not at all. Current and future QIS applications differ from prior applications of quantum mechanics, such as the laser, transistor, and magnetic resonance imaging, by using distinct quantum phenomena—superposition and entanglement—that do not have classical counterparts.

- SaTC: MPS will continue to invest in fundamental research in cybersecurity.

- UtB including the BRAIN Initiative: MPS will continue to invest in the scientific understanding of the full complexity of the brain.

- QL: MPS is the steward for QL, an NSF Big Idea that will build upon and extend our existing knowledge of the quantum world to observe, manipulate, and control, from first principles, the behavior of particles at atomic and subatomic scales. It will enable discoveries in both naturally-occurring and engineered quantum systems and develop next-generation quantum technologies and devices for sensing, information processing, communications, and computing. These advances will unleash the potential of the Nation's quantum-based scientific enterprise to enhance the Nation's well-being, economy, and security.

- WoU: MPS is the steward for WoU, and together with GEO/OPP, will increase support for research in the "windows"—electromagnetic waves, high-energy particles, and gravitational waves, of multi-messenger astrophysics (MMA). Through WoU investments, the MMA research community will understand the universe as never before and enable the U.S. to maintain leadership at the forefront of the astronomical sciences. NSF will grow the workforce not only for multi-messenger astrophysics but also for engineering, data science, and many other areas in our modern society.

MPS Funding for Facilities and Centers Programs

In FY 2020, MPS will invest $88.0 million for Centers, accounting for roughly seven percent of the MPS budget. MPS is maintaining commitments to Science and Technology Centers, the Materials Centers, and the Centers for Chemical Innovation. Operations and maintenance funding for MPS-supported major multi-user facilities comprises approximately 24.0 percent of MPS's FY 2020 Request. MPS has increased operations budgets for facilities to maintain current operational capacity. Where increases were not possible, MPS has maintained operations budgets as close to constant as possible.

MPS Funding for Centers Programs
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual: Amount	Change over FY 2018 Actual: Percent
Total	**$83.22**	**-**	**$88.00**	**$4.78**	**5.7%**
Centers for Chemical Innovation (CHE)	22.01	-	19.00	-3.01	-13.7%
Materials Centers (DMR)	46.40	-	54.00	7.60	16.4%
STC: Center for Integrated Quantum Materials (DMR)	5.00	-	5.00	-	-
STC: STC for Real-Time Functional Imaging (DMR)	5.00	-	5.00	-	-
STC: Center for Bright Beams (PHY)	4.81	-	5.00	0.19	4.0%

For detailed information on NSF Centers programs, please see the NSF-Wide Investments chapter.

MPS Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$388.06**	**-**	**$297.82**	**-$90.24**	**-23.3%**
Arecibo Observatory[1]	8.10	-	2.13	-5.97	-73.7%
Atacama Large Millimeter Array (ALMA)	38.55	-	47.26	8.71	22.6%
Cornell High Energy Synchrotron Source (CHESS)[2]	14.00	-	5.00	-9.00	-64.3%
Daniel K. Inouye Solar Telescope (DKIST)[3]	24.00	-	19.01	-4.99	-20.8%
Gemini Observatory[4]	34.02	-	20.28	-13.74	-40.4%
IceCube Neutrino Observatory (IceCube)	3.50	-	3.50	-	-
Large Hadron Collider (LHC)[5]	32.46	-	20.00	-12.46	-38.4%
Large Synoptic Survey Telescope (LSST)[6]	11.10	-	-	-11.10	-100.0%
Laser Interferometer Gravitational Wave Observatory (LIGO)[7]	49.43	-	45.00	-4.43	-9.0%
National High-Magnetic Field Laboratory (NHMFL)[4,8]	54.16	-	36.78	-17.38	-32.1%
National Optical Astronomy Observatory (NOAO)[4]	26.76	-	22.91	-3.85	-14.4%
National Radio Astronomy Observatories (NRAO)[4,9,10]	44.46	-	38.40	-6.06	-13.6%
National Solar Observatory (NSO)[4]	8.82	-	4.13	-4.69	-53.2%
National Superconducting Cyclotron Laboratory (NSCL)	24.00	-	22.00	-2.00	-8.3%
Other MPS Facilities	14.70	-	11.42	-3.28	-22.3%
Center for High Resolution Neutron Scattering (CHRNS)	2.79	-	3.00	0.21	7.5%
Long Baseline Observatory (LBO)[10]	3.49	-	-	-3.49	-100.0%
Green Bank Observatory (GBO)	8.42	-	8.42	-	-

[1] FY 2018 Actual includes $2.0 million of supplemental funding provided in Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) for repairs related to damage from Hurricane Maria, $1.80 million to fund part of FY 2019 costs, and $580,000 for one-time costs associated with the change in management organization.

[2] FY 2018 Actual includes $10.0 million to fund part of FY 2019 costs. The FY 2020 Request reflects the transition of CHESS from an NSF stewardship to a partnership model.

[3] Includes $2.0 million for cultural mitigation activities per year, as required by the compliance process, through FY 2020. FY 2018 Actual includes $8.0 million to fund part of FY 2019 costs.

[4] FY 2018 Actual includes additional FY 2018 one-time funding above the requested amount: $13.0 million for Gemini; $10.08 million for NHMFL, $7.08 million for NOAO, $3.50 million for NRAO, and $3.50 million for NSO.

[5] FY 2018 Actual includes $16.60 million for High Luminosity-LHC development and design, of which $7.50 million funds FY 2019 and FY 2020 activities.

[6] FY 2018 Actual obligations are intended to fund pre-operations costs for the first three years of the pre-operations ramp up, FY 2019-FY 2021.

[7] FY 2018 Actual includes $10.0 million for Advanced LIGO Plus (LIGO A+) development and design.

[8] FY 2018 includes $9.34 million to fund part of FY 2019 costs.

[9] FY 2018 Actual includes $2.0 million of supplemental funding provided in Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) for repairs related to damage from Hurricane Maria.

[10] FY 2020 Request includes reintegration of the Long Baseline Observatory (LBO) into NRAO as the Very Long Baseline Array (VLBA) at $3.43 million per year.

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

Funding Profile

MPS Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	8,804	-	9,000
Number of New Awards	2,594	-	2,200
Funding Rate	29%	N/A	24%
Statistics for Research Grants:			
Number of Research Grant Proposals	7,619	-	8,000
Number of Research Grants	2,072	-	1,700
Funding Rate	27%	N/A	21%
Median Annualized Award Size	$123,319	-	$120,000
Average Annualized Award Size	$145,679	-	$140,000
Average Award Duration, in years	3.2	-	3.2

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- 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 Space Studies Board of the National Academies of Science, Engineering, and Medicine (the National Academies). The resulting National Academies mid-term review committee report was published in August 2016.[1] Findings and recommendations of the "mid-decadal" report will guide AST decision making and prioritization until superseded by the next "decadal" report, expected in 2021.
- The Astronomy and Astrophysics Advisory Committee (AAAC) met on three occasions during early FY 2018, subsequently completing and delivering its annual report[2] in March 2018 on interagency activities by NSF, the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA). Findings and recommendations of this annual report help guide AST decision making and prioritization.
- DMR co-sponsored, with DOE/BES, a National Academies Decadal Study, entitled *Frontiers of Materials Research: A Decadal Study.*[3] This study, initiated in FY 2016 and completed and published in FY 2019, produced several large and overarching findings and recommendations. The report cited infrastructure, including materials growth and synthesis and advanced characterization and measurement instruments, as areas that need more sustained support. The report also endorsed the recommendations found in the Interagency 2017 Polymer Decadal Study, *Frontiers in Polymer Science and Engineering,*[4] including emphasis on materials sustainable development.
- Pursuant to the National Environmental Policy Act of 1969, AST prepared an Environmental Impact Statement (EIS) for Green Bank Observatory, which was published in February 2019.[5] The Green Bank

[1] http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_161177
[2] www.nsf.gov/mps/ast/aaac.jsp
[3] www.nap.edu/catalog/25244/frontiers-of-materials-research-a-decadal-survey
[4] www.iprime.umn.edu/sites/g/files/pua2396/f/frontiers_in_polymer_science_and_engineering_2016_nsf_workshop_report.pdf
[5] www.nsf.gov/mps/ast/env_impact_reviews/env_rev_greenbank.jsp

EIS studies and evaluates the potential environmental effects of proposed operational changes to Green Bank Observatory due to funding constraints. During the process of preparing the final report the general public has several opportunities to review draft documents and provide external, independent formal input into the formulation of the final EIS.

- The CHE CCI program is currently being assessed, with the evaluation being conducted by Abt Associates, Inc. The study final results are expected in 2019.
- At the request of AST and the DOE, in August 2018 the AAAC established an ad hoc subcommittee to consider and advise AST regarding the evolving roles of the Gemini, Blanco, and SOuthern Astrophysical Research telescope facilities in the area of Multi-Messenger and Time Domain astronomy and astrophysics. The subcommittee held several meetings and provided its report to the AAAC in FY 2019.
- In FY 2018, PHY charged the MPS Advisory Committee to form a subcommittee to assess the Physics Frontiers Centers program. The subcommittee is expected to deliver a report of its findings in FY 2019.
- In FY 2019, NSF and DOE jointly charged the Nuclear Science Advisory Committee (NSAC) to identify unique opportunities for U.S. nuclear physics research to contribute to advances in Quantum Computing and QIS. The report from NSAC is expected later in FY 2019.
- In FY 2018, PHY made an award to the National Academies to initiate the next Decadal Assessment of Plasma Science. The NSF award was co-funded by AST, GEO Division of Atmospheric and Geospace Sciences, and ENG Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET). The study is also co-sponsored by DOE, the Air Force Office of Scientific Research (AFOSR), and the Office of Naval Research. The National Academies report is expected in FY 2020.
- In FY 2019, PHY charged the National Academies with a Decadal Survey of Atomic, Molecular, and Optical Physics, together with DOE/BES. The National Academies report is expected in FY 2020.
- In FY 2019, MPS/CHE, in collaboration with the DOE/Basic Energy Sciences (BES)/Chemical Sciences, Geosciences and Biosciences will initiate an evaluation of overall grand challenges in the field of chemistry. Results are expected to be used to inform the scope of core funding activities and future solicitations and DCLs. Final results from this study are expected in 2020.

<u>Workshops and Reports:</u>

- In January 2018, the current NSF Astronomy and Astrophysics Postdoctoral Fellows organized their 16th annual AST-funded symposium[6] just prior to the American Astronomical Society meeting at National Harbor. Each fellow made two presentations, one on current research and the other on creative contributions to education and outreach.
- In March 2018, the CHE workshop report on “Framing the Role of Big Data and Modern Data Science in Chemistry” was published.[7] The workshop report articulates the role of big data research and modern data science in chemistry. The report addresses the short- and long-term needs that should be met to fully develop this potential and offers suggestions on how this development could be supported.
- In May 2018, Columbia University held a symposium, funded in part by AST, to celebrate and assess 10 years of its NSF-funded Bridge Program, a structured post-baccalaureate transition program for underrepresented minority STEM students interested in admission to competitive PhD programs.
- In May 2018, AST, PHY, and CISE Office of Advanced Cyberinfrastructure sponsored a workshop titled *Cyberinfrastructure for Multi-Messenger Astrophysics* to develop concepts for new community-scale data cyberinfrastructure for timely handling, processing, analysis, and modeling of multi-messenger astrophysical data. The workshop report was published[8] in July 2018.
- In May 2018, a PHY-sponsored workshop[9] on *Developing Flexible and Robust Software in Computational Atomic and Molecular Physics* was held at the Institute for Theoretical Atomic

[6] http://aapf-fellows.org/symposium/2018
[7] www.nsf.gov/mps/che/workshops/data_chemistry_workshop_report_03262018.pdf
[8] https://arxiv.org/abs/1807.04780
[9] www.cfa.harvard.edu/itamp-event/developing-flexible-and-robust-software-computational-atomic-and-molecular-physics-0

Molecular and Optical Physics. The workshop's aim was to identify and prioritize outstanding problems in atomic, molecular and optical physics, which would benefit from a focused community effort to develop new software tools and algorithms. A workshop report is planned for FY 2019.

- DMR sponsored several educational and outreach activities, such as a Young Investigators Workshop[10] in June 2018, and the Quantum Science Summer School,[11] at Cornell University in June 2018, which was supported by NSF, DOE, and AFOSR.
- In October 2018, AST funded a workshop for the PIs of all the NSF Research Experience for Undergraduates Astronomy sites. It was held in conjunction with the Council on Undergraduate Research meeting in Alexandria, Virginia. The purpose was to exchange best practices on key issues, such as recruitment of underrepresented minorities.
- In October 2018, PHY cosponsored a workshop titled *Deep Learning for Multi-messenger Astrophysics: Real-time Discovery at Scale*. A workshop report was published[12] in February 2019.
- In October 2018, DMS sponsored a workshop titled "Statistics at a Crossroads: Challenges and Opportunities in the Data Science Era." The workshop focused on identifying the emerging frontiers of research in statistics and their connections to HDR. The final report will be available in 2019.
- In FY 2018, AST, DMR, and PHY co-funded the 2018 Conference of the National Society of Black Physicists, held in Columbus, Ohio, November 4-7, 2018. Other NSF sponsors are GEO and EHR.
- In November 2018, PHY and BIO Division of Molecular and Cellular Biosciences sponsored a workshop titled *Quantum Biology and Quantum Processes in Biology* that brought together biologists and physical scientists to discuss the role of quantum phenomena in biological systems.
- In November 2018, DMS sponsored a PI workshop on the DMS Research Training Groups (RTG) program. The workshop focused on evaluating the program in terms of broadening participation, innovation, vertical integration, and sustainability and on developing best practices in these areas. The report for RTG has been completed and published.[13]
- In November 2018, DMS sponsored a workshop titled "Graduate Statistics Curriculum at a Crossroads." The workshop focused on identifying challenges and barriers in graduate education in statistics and workforce development in connection to HDR. The final report will be available in 2019.
- In November 2018, DMS sponsored a workshop titled "Rules of Life in the Context of Future Mathematical Sciences". The workshop focused on identifying the emerging frontiers of research in Mathematical Biology and their connections to URoL. The final report will be available in 2019.
- In December 2018, CHE and DMS co-sponsored a Data Science Innovation Lab "Learning the Power of Data in Chemistry" to promote new collaborations between data scientists and chemists for effective collection, analysis, and interpretation of chemical data. This Lab catalyzed new research directions in chemical and mathematical research for solving transformative chemical challenges of the 21st century.
- In FY 2018, CHE partnered with DOE and CBET to support a National Academies consensus study to advance topics for fundamental research in chemical separations science across many application areas—chemical analysis, energy production, waste management, water treatment, chemical manufacturing, recovery of critical resources, mining, paper production, and more. The final report is anticipated in FY 2021.
- DMR organized and sponsored meetings in collaboration with other government agencies and across NSF. Working with DOE/BES, DMR co-sponsored meetings of the Condensed Matter and Materials Research Committee, a standing committee of the National Academies, and in collaboration with ENG Division of Civil, Mechanical & Manufacturing Innovation and AFOSR, DMR organized a joint NSF-

[10] http://reg.conferences.dce.ufl.edu/Physics/1482
[11] http://qs3.mit.edu/index.php/qs3-school-2017/2018-program
[12] https://arxiv.org/abs/1902.00522
[13] www.nsf.gov/mps/dms/documents/RTG_Program_Meeting_Report.pdf

AFOSR-Air Force Research Laboratory workshop in the summer of 2018 focused on Additive Manufacturing.

- In support of the NSF Big Idea QL, DMR, in collaboration with other agencies, sponsored or organized several events, including: (1) a special outreach session focused on Quantum Leap[14] at the American Physical Society Meeting; (2) an invited session chaired by Nobel Prize winner Anthony Leggett, focused on Majorana fermions,[15] at the Materials Research Society Spring Meeting; (3) the Chicago Quantum Summit,[16] devoted to the Quantum Exchange and Triplets programs, where the NSF director and the DMR division director delivered presentations; and (4) a Principal Investigator's Meeting on Moore's Law.[17]
- In 2018 and 2019, DMR sponsored several Gordon Research Conferences covering a wide range of topics, both disciplinary and interdisciplinary, such as granular matter, molecular materials research at high pressure, correlated electron systems, spin dynamics in nanostructures and liquid crystals, as well as several regional meetings in focused areas such as two-dimensional materials, nanomechanical systems, quantum materials, and electronic and photonic materials.
- In January 2019, CHE, PHY, DMR and CISE supported a workshop on "Enabling Quantum Leap: Quantum algorithms for quantum chemistry and materials." The workshop brought together researchers in the fields of chemistry, materials, physics, and computer science to explore mechanisms to advance the science, collaboration, education, and broad impacts of quantum computing as applied to quantum simulation. Industrial participants (e.g., IBM, Microsoft, and Google) demonstrated their quantum computing technologies. The workshop report is expected in summer of 2019.
- In January 2019, a PHY-sponsored workshop titled *Large Ultrahigh-Vacuum Systems for Frontier Scientific Research Instrumentation* was held at the LIGO Livingston site. The goals were to compare vacuum needs of future research facilities and to explore recent advances, new insights, and novel concepts that could render major cost savings in their realization. A report will be published in FY 2019.
- CHE's fourth annual Early Career Investigator Workshop will be held on May 20-21, 2019 in Alexandria, Virginia. The workshop is designed to help about 80 early career faculty in chemistry better design and integrate research, education and outreach goals, while obtaining personalized formative feedback on their research ideas, projects, and plans. The National Institutes of Health (NIH), DOE, AFOSR, Environmental Protection Agency, and other federal agencies will participate.

Committees of Visitors (COV):

- In 2018, there were no COVs in MPS.
- In 2019, COVs will review AST, DMR and PHY.
- In 2020, COVs will review CHE and DMS.

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.

[14] https://meetings.aps.org/Meeting/MAR18/Session/D04
[15] https://mrsspring2018.zerista.com/event/member/464431
[16] https://quantum.uchicago.edu/events/summit2018/
[17] https://sites.google.com/georgetown.edu/nsfworkshop2018/home

People Involved in MPS Activities

Number of People Involved in MPS Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	8,954	-	7,600
Other Professionals	3,562	-	3,000
Postdoctoral Associates	2,276	-	1,900
Graduate Students	9,224	-	8,200
Undergraduate Students	5,668	-	5,400
Total Number of People	**29,684**	**-**	**26,100**

DIVISION OF ASTRONOMICAL SCIENCES (AST) **$217,080,000**
-$94,080,000 / -30.2%

AST Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$311.16**	**-**	**$217.08**	**-$94.08**	**-30.2%**
Research	**65.35**	**-**	**43.44**	**-21.91**	**-33.5%**
CAREER	4.17	-	5.00	0.83	19.9%
Education	**4.73**	**-**	**4.70**	**-0.03**	**-0.6%**
Infrastructure	**241.08**	**-**	**168.94**	**-72.14**	**-29.9%**
Arecibo Observatory[1]	8.10	-	2.13	-5.97	-73.7%
ALMA	38.55	-	47.26	8.71	22.6%
AST Portfolio Review Implementation	0.24	-	-	-0.24	-100.0%
DKIST[2]	24.00	-	19.01	-4.99	-20.8%
Gemini Observatory[3]	34.02	-	20.28	-13.74	-40.4%
LSST[4]	11.10	-	-	-11.10	-100.0%
Midscale Research Infrastructure	32.98	-	5.00	-27.98	-84.8%
NOAO[3]	25.09	-	22.91	-2.18	-8.7%
NRAO[3,5,6]	44.46	-	38.40	-6.06	-13.6%
NSO[3]	8.82	-	4.13	-4.69	-53.2%
Other AST Facilities	11.91	-	8.42	-3.49	-29.3%
LBO[6]	*3.49*	-	-	*-3.49*	*-100.0%*
GBO	*8.42*	-	*8.42*	-	-
Research Resources	1.81	-	1.40	-0.41	-22.5%

[1] FY 2018 Actual includes $2.0 million of supplemental funding provided in Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) for repairs related to damage from Hurricane Maria, $1.80 million in fund part of FY 2019 costs, and $580,000 million for one-time costs associated with the change in management organization.

[2] Includes $2.0 million for cultural mitigation activities per year, as required by the compliance process, through FY 2020. FY 2018 Actual includes $8.0 million to fund part of FY 2019 costs.

[3] FY 2018 Actual includes additional FY 2018 one-time funding above the requested amount: $13.0 million for Gemini; $5.42 million for NOAO, $3.50 million for NRAO, and $3.50 million for NSO.

[4] FY 2018 Actual obligations are intended to cover pre-operations costs for the first three years of the pre-operations ramp up, FY 2019-FY 2021.

[5] FY 2018 Actual includes $2.0 million of supplemental funding provided in Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) for repairs related to damage from Hurricane Maria.

[6] FY 2020 Request includes reintegration of the Long Baseline Observatory (LBO) into NRAO as the Very Long Baseline Array (VLBA) at $3.43 million per year.

About AST

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 via cooperative agreements for the operation of large telescope facilities. These telescope facilities provide world-leading, one-of-a-kind observational capabilities on a competitive basis to thousands of astronomers each year. These facilities also enable scientific advances by making archived data products available to researchers. AST supports the development of advanced technologies and instrumentation and manages the electromagnetic spectrum for scientific use by the entire NSF community.

The AST portfolio includes 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.

AST is substantially engaged in NSF's Big Ideas, including WoU, Mid-scale RI, HDR, and QL. AST co-leads WoU which will probe the universe through several powerful and diverse "windows"—electromagnetic waves, high-energy particles, and gravitational waves. Breakthroughs in astronomical sciences are often enabled by the availability of new facilities and instrumentation. Additionally, with the enormous volumes of data produced by individual astronomical facilities (e.g. 20 terabytes per night at LSST), AST programs are directly relevant to HDR, engaging the research community in pursing data science research toward solving AST related data science problems.

In general, about 23 percent of the AST portfolio is available for new research grants. About 78 percent of AST's budget supports the instrumentation and facilities needed for progress at the frontiers of observational astronomy, while 20 percent supports the research of individual investigators. Through the MREFC appropriation, AST also oversees the construction of LSST and DKIST. For detailed information on individual facilities, please see the Facilities and the Major Research Equipment and Facilities Construction chapters.

DIVISION OF CHEMISTRY (CHE) **$214,180,000**
-$32,110,000 / -13.0%

CHE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$246.29**	**-**	**$214.18**	**-$32.11**	**-13.0%**
Research	**231.98**	**-**	**199.68**	**-32.30**	**-13.9%**
CAREER	28.68	-	21.57	-7.11	-24.8%
Centers Funding (total)	22.01	-	19.00	-3.01	-13.7%
Centers for Chemical Innovation	22.01	-	19.00	-3.01	-13.7%
Education	**4.33**	**-**	**2.60**	**-1.73**	**-40.0%**
Infrastructure	**9.98**	**-**	**11.90**	**1.92**	**19.2%**
NHMFL	1.73	-	1.73	-	-
NNCI[1]	0.30	-	-	-0.30	-100.0%
Midscale Research Infrastructure	-	-	5.00	5.00	N/A
Research Resources	7.95	-	5.17	-2.78	-35.0%

[1] The FY 2020 Request reflects the completion of CHE's contribution to NNCI in FY 2019.

About CHE

The chemical industry is one of the largest and most important industries worldwide both in terms of impact on the economy and employment. This industry includes sectors in energy, pharmaceuticals and medical applications, electronics, agriculture, textiles, plastics, coatings, building products, and numerous other commercial and consumer products. Specifically, CHE enables research on the synthesis and characterization of new molecules, surfaces, and nanostructures (by both theoretical and experimental methods) that leads to usable products beneficial to all of society.

CHE contributes to several of NSF's Big Ideas including: HDR, by promoting data sciences to effectively and efficiently use the extensive volumes and varieties of chemical data in order to advance new chemical discovery and innovation; QL, by contributing to the understanding and use of quantum phenomena in computing and sensing applications, to understanding quantum functions in living and synthetic systems, and to providing chemical algorithms suitable for testing the supremacy of quantum versus digital computing; and URoL, by increasing knowledge of the structure-function relationships in biological systems leading to important advances in understanding the human body and improving health. CHE also participates actively in convergence research encouraging researchers to integrate chemical learning and understanding with biology, engineering, materials research, geosciences, computing, and other scientific and technical fields. All of these areas not only drastically expedite chemical discovery but also have significant ramifications for training the next generation of scientists and engineers.

CHE will continue to support the REU program in FY 2020, with projected funding rates for REU Sites expected to be similar to proposals submitted to CHE core research programs.

CHE is also actively engaged in the development of new mid-scale instrumentation to examine and solve complex chemical problems including the synergistic combinations of multiple types of measurement (including remote access and cyber-enabled tools) and the development of novel, new instruments. Involvement in midscale research infrastructure programs enables tool development, which is essential for continuing progress in fields as diverse as understanding the brain, sensing for agriculture and defense applications, discovering new chemical compounds for microelectronics and environmentally-friendly plastics, and improving the sustainable and responsible advanced manufacturing of chemical feedstocks as they transition from the lab bench to commercial scales. The importance of these investments is reflected in CHE's FY 2020 funding profile with a shift in funding from small instrument to midscale chemistry infrastructure investments. CHE midscale investments are expected to impact priority areas including URoL, QL, HDR, and other frontier areas critical to chemistry.

In general, about 75 percent of the CHE portfolio is available to support new research grants. The remaining 25 percent supports research grants made in prior years and the research infrastructure needed by the chemistry community.

DIVISION OF MATERIALS RESEARCH (DMR) **$273,780,000**
-$63,360,000 / -18.8%

DMR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$337.14**	**-**	**$273.78**	**-$63.36**	**-18.8%**
Research	**244.68**	**-**	**204.37**	**-40.31**	**-16.5%**
CAREER	23.95	-	23.04	-0.91	-3.8%
Centers Funding (total)	56.40	-	64.00	7.60	13.5%
Materials Centers	46.40	-	54.00	7.60	16.4%
STC: Center for Integrated Quantum Materials	5.00	-	5.00	-	-
STC: Real-time Functional Imaging	5.00	-	5.00	-	-
Education	**5.14**	**-**	**2.13**	**-3.01**	**-58.6%**
Infrastructure	**87.31**	**-**	**67.28**	**-20.03**	**-22.9%**
CHESS[1]	14.00	-	5.00	-9.00	-64.3%
CHRNS	2.79	-	3.00	0.21	7.6%
Midscale Research Infrastructure[2]	9.71	-	20.20	10.49	107.9%
NHMFL[3]	52.43	-	35.05	-17.38	-33.1%
NNCI	2.58	-	2.58	-	-
Research Resources[4]	5.80	-	1.45	-4.35	-75.0%

[1] FY 2018 Actual includes $10.0 million to fund part of FY 2019 costs. The FY 2020 Request reflects the transition of CHESS from an NSF stewardship to a partnership model.

[2] FY 2018 Actual includes forward funding of $6.0 million to support the Materials Innovation Platform program. FY 2020 reflects a new competition, with up to four Materials Innovation Platform awards to be funded.

[3] FY 2018 Actual includes additional FY 2018 one-time funding in the amount of $10.08 million above the requested amount for facility upgrades, and $9.34 million to fund part of FY 2019 costs.

[4] FY 2018 Actual includes an investment of $4.35 million to support additional Major Research Instrumentation awards. This investment will not be funded in FY 2020.

About DMR

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 supports basic experimental and theoretical materials research via 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 fields. This enterprise is dependent on investments across scales: from single investigators to teams and centers, from singularly focused research to that requiring interdisciplinarity, and from small instruments to large-scale facilities.

DMR contributes to several Big Ideas, including QL, HDR, and URoL, as well as maintaining divisional programs in midscale research infrastructure and convergence research that complement the Mid-scale RI and GCR. In addition, DMR advances administration priorities in Advanced Manufacturing and the Materials Genome Initiative through the Designing Materials to Revolutionize and Engineer our Future and the Materials Innovation Platform programs.

In general, about 34 percent of the DMR portfolio is available to support new research grants. The remaining 66 percent supports research grants made in prior years and the research infrastructure needed by materials research community.

DIVISION OF MATHEMATICAL SCIENCE (DMS) **$203,260,000**
-$34,430,000 / -14.5%

DMS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$237.69**	**-**	**$203.26**	**-$34.43**	**-14.5%**
Research	**225.34**	**-**	**192.36**	**-32.98**	**-14.6%**
CAREER	15.42	-	12.00	-3.42	-22.2%
Education	**12.35**	**-**	**10.90**	**-1.45**	**-11.7%**

About DMS

DMS provides major U.S. federal support of basic research at the frontiers of mathematical sciences. Modern communication, transportation, medicine, manufacturing, energy, security, and finance all depend on new developments in the mathematical sciences. DMS investments catalyze research at the forefront of fundamental, applied and computational mathematics, and statistics necessary to support discovery and innovation in these national priority areas as well as many science and engineering fields. In turn, advances in science and engineering inspire development of more sophisticated and effective mathematical and statistical methodologies, theories, and tools. DMS investments also support the training of future researchers in the mathematical and statistical sciences.

In addition to supporting a vibrant research community through core programs in mathematics and statistics, DMS supports the Mathematical Sciences Research Institutes program that advances mathematics and statistics research, and expands the U.S. talent base engaged in mathematical and statistical research.

Through strong partnerships with other entities, DMS is able to support foundational research across a much broader set of programs. In partnership with other divisions at NSF, DMS provides support for several of the NSF Big Ideas, including HDR, URoL, and QL. Other partnerships include two joint programs in biosciences with NIH; a joint program with the National Geospatial Intelligence Agency to develop the next generation of mathematical and statistical algorithms for analysis of large spatiotemporal datasets; and a joint program on Algorithms for Modern Power Systems with DOE. Additional examples of partnerships include a joint program in data sciences with CISE to support the development of institutes called the Transdisciplinary Research in Principles of Data Science, as well as a joint program with BIO and the Simons Foundation to support research centers on the Mathematics of Complex Biological Systems.

In general, about 48 percent of the DMS portfolio is available to support new research grants each year. The remaining 52 percent supports research grants made in prior years and the research infrastructure needed by the mathematics and statistics communities.

DIVISION OF PHYSICS (PHY)

$247,500,000
-$63,250,000 / -20.4%

PHY Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$310.75**	**-**	**$247.50**	**-$63.25**	**-20.4%**
Research	**182.35**	**-**	**145.63**	**-36.72**	**-20.1%**
CAREER	10.14	-	6.78	-3.36	-33.1%
Centers Funding (total)	4.81	-	5.00	0.19	4.0%
STC: Center for Bright Beams	4.81	-	5.00	0.19	4.0%
Education	**4.50**	**-**	**4.70**	**0.20**	**4.4%**
Infrastructure	**123.90**	**-**	**97.17**	**-26.73**	**-21.6%**
IceCube	3.50	-	3.50	-	-
LHC	15.86	-	20.00	4.14	26.1%
LIGO	39.43	-	44.60	5.17	13.1%
Midscale Research Infrastructure	14.42	-	6.67	-7.75	-53.7%
NSCL	24.00	-	22.00	-2.00	-8.3%
Research Resources	0.09	-	-	-0.09	-100.0%
Facilities Design Stage Activities (total)	26.60	-	0.40	-26.20	-98.5%
High Luminosity-LHC[1]	16.60	-	-	-16.60	-100.0%
Advanced LIGO Plus (LIGO A+)	10.00	-	0.40	-9.60	-96.0%

[1] FY 2018 Actual reflects $7.50 million of funding for FY 2019 and FY 2020 development and design. No additional funds are expected in these years.

About PHY

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 U.S. research in gravitational physics and the leading supporter of fundamental research in atomic, molecular, and optical physics in the United States. PHY is a major partner with DOE in support of elementary particle physics, nuclear physics, and plasma physics. PHY also has the only U.S. program designed for the support of physics research in living systems. The development of the most advanced cutting-edge computational resources, innovative technology, and new instrumentation is a key part of physics research. Tools developed by the physics community continuously have major impacts in other scientific and engineering fields. As a result, the division contributes to building the foundation for several of NSF's Big Ideas including: WoU, QL, URoL, and HDR. PHY is also initiating an MREFC project to upgrade the A Toroidal LHC ApparatuS Detector (ATLAS) and Compact Muon Solenoid (CMS) detectors at the European Organization for Nuclear Research (CERN) to take advantage of the high luminosity expected in 2026 at the LHC.

In general, about 22 percent of the PHY portfolio is available for new research grants. The remaining 78 percent is used primarily to fund continuing grants made in previous years (about 42 percent) and to support operations and maintenance for four facilities that are a key part of the division portfolio (about 36 percent).

OFFICE OF MULTIDISCIPLINARY ACTIVITIES (OMA) **$100,020,000**
+$39,630,000 / 65.6%

OMA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$60.39**	**-**	**$100.02**	**$39.63**	**65.6%**
Research	**49.37**	**-**	**95.02**	**45.65**	**92.5%**
CAREER	0.50	-	-	-0.50	-100.0%
Big Idea: QL	-	-	30.00	30.00	N/A
Big Idea: WoU	-	-	30.00	30.00	N/A
Education[1]	**9.11**	**-**	**-**	**-9.11**	**-100.0%**
Infrastructure	**1.91**	**-**	**5.00**	**3.09**	**162.4%**
AST Portfolio Review Implementation	0.24	-	5.00	4.76	1948.0%
NOAO[2]	1.66	-	-	-1.66	-100.0%

[1] NSF INCLUDES and NSF Research Traineeship are centrally funded by EHR in FY 2020; no OMA funding is contributed to these programs.

[2] FY 2018 Actual reflects additional one-time funding above the requested amount.

About OMA

OMA co-funds research that is relevant to the broad swath of scientific disciplines represented in the five disciplinary divisions of MPS. 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 2020, OMA funding priorities will focus on MPS-relevant Big Ideas. MPS is the steward for the NSF-wide investment of funds designated for QL. Investments will emphasize projects that engage several relevant disciplines in a convergent and interdependent manner. An important focus for OMA in FY 2020 will be strategic investments in QL, co-funding research projects to advance quantum science and technology. This Big Idea will involve, in addition to all five of the MPS divisions, ENG, CISE, and BIO, among others. Societal benefits of this science and technology are expected to be significant, as it is poised to include proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts. MPS is also the steward for NSF-wide investment of funds for WoU. Participants include AST, PHY, and OPP in GEO. The WoU activities will bring together fundamental research in electromagnetic waves, high-energy particles, and gravitational waves; advance the study of the universe; and grow the nation’s multi-messenger astrophysics, engineering, and data science workforce. OMA will also invest in other multidisciplinary research that advances the basic foundations of mathematical and physical sciences and furthers NSF’s investments in the Big Ideas.

OMA will also provide leadership and support for I-Corps™ activities within MPS, which began in FY 2016. OMA, in partnership with MPS disciplinary programs, purposefully invests in grants to principal investigators at Historically Black Colleges and Universities (HBCUs) to foster excellence in research. Finally, in FY 2020, OMA will continue to provide targeted support for graduate students from historically underrepresented groups via the Alliances for Graduate Education and the Professoriate (AGEP) - Graduate

Research Supplement program, which provides research supplements to projects at institutions that have an active or legacy AGEP award, and the Graduate Research Supplements to Veterans program.

In general, about 70 percent of the OMA portfolio is available to support new research grants. The remaining 30 percent supports multidisciplinary research infrastructure and education activities needed by the MPS community.

DIRECTORATE FOR SOCIAL, BEHAVIORAL, AND ECONOMIC SCIENCES (SBE) **$230,076,000**
-$20,612,000 / -8.2%

SBE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Social and Economic Sciences (SES)	$87.05	-	$80.58	-$6.47	-7.4%
Behavioral and Cognitive Sciences (BCS)	86.60	-	78.97	-7.63	-8.8%
National Center for Science and Engineering Statistics (NCSES)	53.46	-	48.80	-4.66	-8.7%
SBE Office of Multidisciplinary Activities (SMA)	23.57	-	21.73	-1.85	-7.8%
Total	**$250.69**	**-**	**$230.08**	**-$20.61**	**-8.2%**

About SBE

SBE research occurs in core areas such as economics, neuroscience, and statistics, as well as multidisciplinary activities such as those described in NSF's 10 Big Ideas.

SBE researchers examine a wide range of fundamental questions about human brains, behaviors, and institutions. SBE provides approximately 62 percent of the federal funding for basic research at academic institutions in the social, behavioral, and economic sciences. This work strengthens knowledge that innovators in the private and public sector go on to apply. SBE researchers' findings have the potential to help to grow the economy, secure the homeland, improve the health and safety of American families, and increase the competitiveness of America's farms, offices, and factories.

SBE seeks to invest in the next generation of truly transformative and socially beneficial science. SBE support for early career investigators, undergraduates and post-doctoral research fellowships, trains and prepares young scholars to develop rigorous and effective new ways to capitalize on the growing availability of massive amounts 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 seed the next harvest of discoveries in the social, behavioral, and economic sciences.

NCSES, an organization within SBE, provides statistical information about the United States' Science and Engineering (S&E) enterprise. NCSES collects and analyzes data on research and development, the S&E workforce, the condition and progress of science, technology, engineering, and mathematics (STEM) education, and U.S. competitiveness in science, engineering, technology, and research and development. NCSES is the Nation's leading provider of statistical data on the S&E enterprise.

SBE's FY 2020 Request is shaped by four guiding principles:

1. Support fundamental research that advances key national priorities. Today, emphases include enhancing individual safety and national security, creating new economic opportunities for populations adversely affected by change, and empowering American innovation through research in such areas as human performance, productivity, worker well-being, information exchange, decision making, and evaluations of collective action and workflow effectiveness and efficiency in a growing range of work environments.
2. Continue to support and advance NSF's Big Ideas, particularly those for which human perceptions,

actions, and adaptive strategies are critical for interdisciplinary science to produce transformative social benefits;
3. Support NCSES; and
4. Invest in broad cross-directorate activities whose ability to improve quality of life depends on accurate and actionable knowledge of human perception, action, and ability.

As an example of SBE's partnerships, SBE will continue in FY 2020 to invest in the foundational research and engineering underlying the FW-HTF Big Idea. FW-HTF will engage research communities to 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 to human benefit. SBE's existing disciplinary and interdisciplinary programs support basic research on opportunities and constraints of human capability, artificial intelligence, machine learning, information processing, decision-making, human adaption to technology, responsible and ethical use of data, and the effect of technological change on the workforce, all of which are intellectual underpinnings for FW-HTF. SBE research in this domain supports efforts to improve lifelong learning and to integrate human values and social dynamics into the algorithms and programs that are transforming modern life. SBE is partnering with CISE, ENG, OIA, and EHR in this Big Idea.

SBE's FY 2020 Request for the URoL Big Idea supports basic, foundational research on the neural mechanisms underlying human behavior, cognition, and social interactions; human genetic variation; the emergence of phenotype from gene-environment interactions; the human microbiome and its co-evolution with its human hosts; and the ethical and social implications and societal acceptance of new scientific technologies, such as tools for genetic engineering and synthetic biology.

SBE's FY 2020 Request for the HDR Big Idea supports foundational research on machine learning, data analytics, computational simulations, technologies, and statistical methodologies. Understanding human dynamics is also critical in the area of cybersecurity and cyberinfrastructure. The HDR Big Idea encompasses a wide range of data-centered activities and SBE actively collaborates with CISE on many projects in this domain—such as the new work with the Partnership for Artificial Intelligence (AI)[1] and a CISE-led workshop on responsible data science. More generally, SBE is partnering with CISE, EHR, MPS, ENG, and other directorates to build the knowledge required to convert unprecedented changes in computing power into transformative practices and usable technologies that can improve quality of life for all.

SBE in FY 2020 will continue to participate in the NNA Big Idea. NNA seeks to advance understanding and explanation of the rapid and complex environmental and social changes in the Arctic region, and to provide the tools and knowledge that will enable resilience in this important part of our world. Changes in this part of the world provide new opportunities for commerce and new challenges for people and places in the region. SBE's partnership with NSF's other directorates can help Americans more effectively understand and adapt to this new world. Specifically, SBE sciences are critical in understanding the opportunities, challenges, and adaptive capacities of individuals who, and communities that, will be affected by ongoing Arctic change.

In addition to its support of the NSF Big Ideas, SBE's FY 2020 Request continues its commitment to broad and dynamic partnerships across the foundation that address fundamental scientific questions with broad public impact. These activities include SaTC, UtB, and INFEWS. Today more than ever, understanding the human element is essential to safety, security, growth, and well-being. SBE is committed to supporting the science that will help America's innovators improve quality of life for all its citizens.

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[1] www.nsf.gov\pubs\2019\nsf19018\nsf19018.jsp

Major Investments

SBE Major Investments
(Dollars in Millions)

Area of Investment	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Artificial Intelligence (AI)	$12.22	-	$10.32	-$1.90	-15.5%
INFEWS	2.50	-	2.00	-0.50	-20.0%
NCSES	53.46	-	48.80	-4.66	-8.7%
I-Corps™	0.50	-	0.50	-	-
SaTC	4.00	-	4.00	-	-
UtB	28.43	-	25.00	-3.43	-12.1%
Brain Initiative	*6.33*	-	*5.33*	*-1.00*	*-15.8%*

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

- AI ($10.32 million): SBE will continue support for AI research. Key areas of investment include such activities as advancing machine learning (ML); developing natural language processing models; integrating ML advances using big data with learning mechanisms developed in cognitive science; developing new statistical inferences and algorithms for the analysis of large data sets; and understanding the legal and ethical implications of AI.

- INFEWS ($2.0 million): SBE will participate in this NSF-wide initiative to explore the interactions among food, energy, and water (FEW) systems. Specifically, SBE will support well-integrated interdisciplinary research efforts to understand, model, design, and manage these interconnected systems that involve social and 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.

- I-Corps™ ($500,000): In FY 2020, SBE will support this multiyear effort to strengthen collaboration between SBE scientists in academia and the technological, entrepreneurial, and business communities and practitioners. SBE supports researchers in developing, implementing, and improving processes by which innovators can bring scientific advances to market and help scientists more effectively benefit the public.

- SaTC ($4.0 million): SBE will sustain its investment in SaTC to support the foundational research on human beings that can improve and strengthen efforts to increase cybersecurity. SBE research can contribute to society's attempts to build infrastructure that facilitates innovation at the same time that it protects individuals, families, communities, and a full array of private and public sector institutions.

- UtB ($25.0 million): SBE will continue support of research advancing an integrative and comprehensive understanding of the brain and its function in context and in action. Investments will support cognitive science, augmented intelligence, and neuroscience (including the BRAIN Initiative), as well as new research at the interface of computational and engineering science, cognitive science, and education research.

Funding Profile

SBE Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,130	-	4,100
Number of New Awards	943	-	900
Funding Rate	23%	N/A	22%
Statistics for Research Grants:			
Number of Research Grant Proposals	3,050	-	3,050
Number of Research Grants	592	-	550
Funding Rate	19%	N/A	18%
Median Annualized Award Size	$123,139	-	$123,000
Average Annualized Award Size	$140,765	-	$141,000
Average Award Duration, in years	2.6	-	2.6

SBE supports investment in core research and education activities as well as research infrastructure. In FY 2020, SBE will continue to fund research in areas such as the NSF Big Ideas, AI, UtB, and cybersecurity research while continuing to prioritize its disciplinary and interdisciplinary investigator-led research areas.

In FY 2020, SBE expects to award approximately 900 competitive grants, including an estimated 550 research grants

Program Monitoring and Evaluation

<u>Workshops and Reports:</u>
In FY 2018, NCSES funded a 27-month study by Committee on National Statistics (CNSTAT) of the National Academies of Sciences, Engineering, and Medicine (the National Academies). The study will have two components: (i) a panel study on transparency and reproducibility for NCSES statistics, and (ii) a workshop on the implications of convergence for measuring the S&E workforce and the S&E enterprise. The desired objective of the consensus panel is to enable NCSES to enhance the transparency and reproducibility of NSF's statistics by and for data users and to facilitate improvement of the statistical program workflow processes of the agency and its contractors. The results are expected to help NCSES improve its processes for producing indicators from its surveys and from blended data sources, and to help data users better understand and apply NCSES data. The desired objective of the workshop is to identify and discuss issues in measuring "convergence" and consider the implications of these issues for the S&E workforce and, more broadly, for the overall S&E enterprise. The results of the workshop are expected to improve NCSES's ability to take account of convergence in its statistical programs. The start-date for the grant was September 2018; the results from the workshop and the panel study are expected to be delivered in 2020.

As part of an existing SES-managed award, partially funded by NCSES, the Committee on National Statistics (CNSTAT) of the National Academies conducted a Consensus Panel Study to assess the NCSES approach to measuring the S&E workforce. The final report[2] from the study, which was delivered to NCSES in January 2018, spelled out several recommendations intended to improve the Center's ability to examine emerging S&E workforce issues while also allowing for stability in the estimation of key trends. Included

[2] www.nap.edu/catalog/24968/measuring-the-21st-century-science-and-engineering-workforce-population-evolving

among the Panel Study's recommendations were suggestions: (i) to accelerate the Center's efforts in developing sample designs that would facilitate the generation and analysis of longitudinal data on S&E workers; (ii) to enhance survey data related to the need for and acquisition of S&E skills and training; and (iii) to conduct research on optimal contacts, response modes, and incentives to improve the efficiency and effectiveness of the Center's S&E workforce surveys program. In response to recommendation (i), NCSES has developed longitudinal weights for its National Survey of College Graduates and has incorporated a longitudinal design into its Survey of Doctorate Recipients with plans to disseminate longitudinal data after the 2019 survey cycle. For recommendation (ii), NCSES has begun assessing the quality and accessibility of administrative data sources to supplement the labor market data collected in its surveys. In response to recommendation (iii), NCSES has conducted research examining data collection approaches to develop an optimal contact strategy for each of its surveys.

In response to requests for increased granularity in graduate student enrollment data, NCSES conducted an evaluation of its Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS). This evaluation included workshops with GSS stakeholders to determine data needs, studies to evaluate options for expanding the analytical capabilities of the survey, and site visits with educational institutions to determine the feasibility of collecting additional information. The result of this evaluation is the successful implementation of an improved GSS data collection effort that allows for the separate analysis of master's graduate student and doctoral graduate student enrollment data. In the past, it was not possible to use GSS data to examine graduate student enrollment by degree level.

Committees of Visitors (COV):
- In 2019, COVs will review BCS and SMA.
- In 2020, a COV will review SES.

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.

People Involved in SBE Activities

Number of People Involved in SBE Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	1,416	-	1,300
Other Professionals	429	-	390
Postdoctoral Associates	167	-	150
Graduate Students	1,290	-	1,180
Undergraduate Students	1,076	-	990
Total Number of People	**4,378**	**-**	**4,010**

DIVISION OF SOCIAL AND ECONOMIC SCIENCES (SES) **$80,580,000**
-$6,470,000 / -7.4%

SES Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$87.05**	**-**	**$80.58**	**-$6.47**	**-7.4%**
Research	**76.46**	**-**	**74.09**	**-2.37**	**-3.1%**
CAREER	2.27	-	2.50	0.23	10.1%
Education	**1.30**	**-**	**0.40**	**-0.90**	**-69.2%**
Infrastructure	**9.29**	**-**	**6.09**	**-3.20**	**-34.4%**
NNCI	0.40	-	-	-0.40	-100.0%
Research Resources	8.89	-	6.09	-2.80	-31.5%

About SES

SES supports research and related activities that improve understanding of economic and social institutions and how individuals and organizations behave within them. SES funds basic research on risk assessment and decision-making in vital areas of society; the ways in which changes in science and technology are affecting people—and when effects are negative, the work provides stronger foundations for effective adaptation. SES funds research on methods and statistics that are used across the sciences, government, education, and industry, to produce more comprehensive, rigorous, reliable, and usable inferences from the many types of data that are now available. Discipline-based programs like economics provide crucial insights pertinent to the social effects of innovation and disruptive technologies—providing the basic ideas that help individuals, communities, governments, and business adapt more effectively. SES also funds work to improve the effectiveness and efficiency of public policy provision and to enhance critical security and preparedness issues. SES coordinates the Cultivating Cultures of Ethical STEM (CCE-STEM) program, supporting, along with other NSF directorates, the Online Ethics Center for Engineering and Science. SES research also helps to clarify how organizations of all kinds can be more effective in increasingly competitive marketplaces and how individuals can find new opportunities to participate in America's evolving workforce.

In general, about 67 percent of the SES portfolio is available to support new research grants. The remaining 33 percent supports research grants made in prior years and the research infrastructure needed by this community.

DIVISION OF BEHAVIORAL AND COGNITIVE SCIENCES (BCS) **$78,970,000**
-$7,630,000 / -8.8%

BCS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$86.60**	**-**	**$78.97**	**-$7.63**	**-8.8%**
Research	**83.46**	**-**	**77.53**	**-5.93**	**-7.1%**
CAREER	2.34	-	2.50	0.16	6.8%
Education	**1.64**	**-**	**0.44**	**-1.20**	**-73.2%**
Infrastructure	**1.50**	**-**	**1.00**	**-0.50**	**-33.3%**
Research Resources	1.50	-	1.00	-0.50	-33.3%

About BCS

BCS supports research and related activities that advance fundamental understanding of human behavior and cognition. BCS's foundational research programs and activities support research in cognitive neuroscience; geography and spatial sciences; linguistics; archaeology; anthropology; social psychology; developmental sciences; perception, action and cognition; and the science of learning including augmented intelligence. Core programs are complemented by active involvement in competitions that support collaborative and cross-disciplinary projects that increase understanding of mind, brain, and society. Multiple programs support research on how artificial intelligence technologies can support or enhance human performance, and new methods in data science are being used to integrate complex and diverse data to better understand human behavior.

The division seeks to advance scientific knowledge and methods addressing perception, thought processes, language, learning, and social behavior across neural, individual, family, and group levels. BCS supports activities focusing on how human behavioral 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 individuals, communities, and many people in the private and public sectors predict and address how people respond to stressors, how to improve methods for effective learning, how to support human performance using emerging technologies, how to effectively expand participation in the STEM workforce, how to enhance the quality of social interaction, and how to strengthen and improve how we anticipate and respond to critical issues in areas such as national security, terrorism, and global change.

In general, about 86 percent of the BCS portfolio is available to support new research grants. The remaining 14 percent supports research grants made in prior years and the research infrastructure needed by this community.

NATIONAL CENTER FOR SCIENCE AND ENGINEERING STATISTICS (NCSES) — $48,800,000 / -$4,660,000 / -8.7%

NCSES Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$53.46**	**-**	**$48.80**	**-$4.66**	**-8.7%**
Education	**0.10**	**-**	**-**	**-0.10**	**-100.0%**
Infrastructure	**53.36**	**-**	**48.80**	**-4.56**	**-8.5%**

About NCSES

NCSES was established within NSF 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 mandated to collect 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. NCSES also support research using the data it collects and on methodologies in areas related to the work of the Center. As a part of its service to the nation, NCSES supports 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 primary 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 S&E 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*.

The FY 2020 Request supports NCSES's core data collection and analytic activities that includes nationally-representative surveys of U.S. investment in research and development (across all sectors of the economy), the education of scientists and engineers, and the science and engineering workforce. This includes the preparation of the aforementioned *Science and Engineering Indicators, and Women, Minorities, and Persons with Disabilities in Science and Engineering.* In FY 2020, NCSES will continue with initiatives related to the use of administrative and organic data, and to maintain systems and data collection efforts.

SBE OFFICE OF MULTIDISCIPLINARY ACTIVITIES (SMA) **$21,726,000**
-$1,848,000 / -7.8%

SMA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$23.57**	**-**	**$21.73**	**-$1.85**	**-7.8%**
Research	**15.98**	**-**	**14.69**	**-1.30**	**-8.1%**
CAREER	0.64	-	-	-0.64	-100.0%
Education	**6.50**	**-**	**5.95**	**-0.55**	**-8.5%**
Infrastructure	**1.09**	**-**	**1.09**	**-**	**-**
Research Resources	1.09	-	1.09	-	-

About SMA

SMA provides a focal point for the wide range of activities that cut across SBE and NSF disciplinary boundaries. SMA supports research that seeks to improve the effectiveness of the scientific workforce. It also supports Research Experiences for Undergraduates (REU) Sites, and SBE Postdoctoral Research Fellowships (SPRF). SMA will play a major role in several crosscutting NSF investments in FY 2020: UtB; cybersecurity, via SaTC; innovation, via I-Corps™; and interdisciplinary research and training, via activities such as the SPRF-Fundamental Research (SPRF-FR) and Broadening Participation (SPRF-BP) tracks. While all SBE divisions pursue interdisciplinary work, SMA assists with seeding multidisciplinary activities for the future, such as leveraged and targeted co-funding directed towards national, NSF, and directorate priorities.

OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE)

$46,240,000
-$2,740,000 / -5.6%

OISE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$48.98**	**-**	**$46.24**	**-$2.74**	**-5.6%**

About OISE

OISE is the focal point for NSF's 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 for U.S. researchers through access to international knowledge, infrastructure, and capabilities. OISE's FY 2020 Request supports this by focusing on three activities: (1) promoting the development of a globally engaged workforce, (2) facilitating and supporting international partnerships, and (3) providing opportunities for U.S. leadership to shape the global science and engineering agenda.

In FY 2018, OISE launched the Accelerating Research through International Networks (AccelNet) program through a call for white papers, funded four workshops, and released a solicitation for funding in FY 2019. The goals of the AccelNet program are to accelerate the process of scientific discovery and prepare the next generation of U.S. researchers for multiteam international collaborations. The AccelNet program supports strategic linkages among U.S. research networks and complementary networks abroad that will leverage research and educational resources to tackle grand scientific challenges that require significant coordinated international efforts. The program seeks to foster high-impact science and engineering by providing opportunities to create new collaborations and new combinations of resources and ideas among linked global networks. At the FY 2020 Request level, OISE will release a modified solicitation using lessons learned from the FY 2019 competition. OISE expects the FY 2020 solicitation to use new mechanisms for the international research community to accelerate discovery through network-to-network collaboration. In FY 2020, AccelNet will focus on NSF-priority investment areas, including NSF's Big Ideas. Each AccelNet award will build a network of networks across international and interdisciplinary boundaries. AccelNet 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.

In FY 2020, OISE will continue to expand opportunities for STEM undergraduate and graduate students through the International Research Experiences for Students (IRES) program. The IRES program supports the development of a diverse, globally-engaged U.S. science and engineering workforce. The IRES program supports active research in all disciplines of research funded by NSF. Given the increasingly global nature of science and engineering, the long-term goal of IRES is to enhance U.S. leadership by developing the next generation of STEM leaders. In FY 2020, IRES will continue to focus on three tracks. Track I focuses on the development of world-class research skills in international cohort experiences. Track II is dedicated to targeted, intensive learning and training opportunities that leverage international knowledge at the frontiers of research. Track III calls for U.S. institutional partnerships and coalitions to develop and evaluate innovative models for high-impact, large-scale international research and professional development experiences for graduate students, as individuals or groups.

In FY 2018, NSF launched MULTIPLIER—MULTIPlying Impact Leveraging International Expertise in

Research Missions. MULTIPLIER replaced NSF's static international strategy of maintaining three overseas offices. MULTIPLIER expeditions focus on fields of science and engineering where researchers are making significant developments and have the potential to benefit U.S. prosperity, security, health, and well-being. MULTIPLIER expands NSF's commitment to international outreach by:

- Identifying emerging scientific research areas worldwide through a collaborative survey approach;
- Providing subject matter experts and international specialists to apply analytic approaches and diplomatic connections to leverage international capabilities that may benefit the U.S.;
- Organizing short-term missions for information gathering, ground truthing and network building; and
- Preparing analysis on country- and discipline-specific insights, as well as reports and presentations.

In FY 2020, OISE will support the Partnerships in International Research and Education (PIRE) program through continuing awards. PIRE is an NSF-wide program that funds international research opportunities for U.S. investigators across all NSF-supported disciplines. PIRE also supports high quality research and education that could not occur without international collaboration. PIRE seeks to catalyze a higher level of international engagement in the U.S. science and engineering community. The PIRE program is currently paused for submission of new proposals. The release of a new solicitation is anticipated for FY 2021, with funding in FY 2022.

OISE will continue to co-fund with NSF directorates on meritorious proposals that include international collaboration through its Global Venture Fund. OISE will provide support to assure that U.S. researchers contribute to, and benefit from, complementary efforts around the globe.

In FY 2019, OISE will contribute to the NNA and QL NSF Big Ideas.

- In FY 2020, OISE will continue supporting NNA at a level of $1.0 million, which will support research that builds on and extends existing observing networks and scientific knowledge as well as logistics support expertise to address the convergent scientific challenges in the changing Arctic. Interagency, state government, and international partnerships will be further developed to achieve pan-Arctic and Arctic-global perspectives.
- In FY 2020, OISE will invest in QL at a level of $1.0 million. The Quantum Leap Big Idea will continue to build upon and extend the existing knowledge of the quantum world, fostering breakthroughs in the fundamental understanding of quantum phenomena and enabling the exploitation of these phenomena to disrupt the Nation's science and engineering landscape. These advances will unleash the potential of the Nation's quantum-based scientific enterprise, economy, and security.

Funding Profile

OISE Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	234	-	300
Number of New Awards	52	-	70
Funding Rate	22%	N/A	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	225	-	100
Number of Research Grants	43	-	40
Funding Rate	19%	N/A	40%
Median Annualized Award Size	$100,000	-	$100,000
Average Annualized Award Size	$138,888	-	$150,000
Average Award Duration, in years	2.7	-	2.3

In FY 2020, the number of competitive proposals is expected to increase as a result of AccelNet proposal submissions. AccelNet funds network-to-network collaborations and not research, so while the total number of competitive proposals will increase, the number of research grant proposals is expected to decrease by 55 percent compared to the FY 2018 Actual Estimate. OISE expects to award about 40 research grants from the IRES program. The decrease in the number of expected research proposals in FY 2020 is attributed to the pause of the PIRE program.

Program Monitoring and Evaluation

External Program Evaluations and Studies:
An evaluation of the IRES program began in September 2018 and will produce deliverables at various stages of the evaluation. The evaluation is expected to be completed in early 2021. The evaluation will review educational and career trajectories of principal investigators and students and the extent of their international engagement as a result of participating in the program. The final results are expected by Fall 2021.

Workshops and Reports:
In FY 2018, five workshops were funded through the AccelNet program to stimulate the exchange of ideas and leverage international resources.

Committees of Visitors (COV):
- December 2017, a COV convened to review OISE's programs and activities. The COV chair presented the report to the NSF International Science and Engineering Advisory Committee January 2018. OISE responded to the COV's recommendations in February 2018.[1]
- Spring 2018, a COV reviewed awards to the National Academies of Sciences, Engineering, and Medicine (the National Academies) Board on International Science Organizations (BISO). BISO's mission is to strengthen science for the benefit of society through U.S. leadership, collaboration, and representation in international scientific organizations and initiatives. BISO provides information about these international scientific organizations and initiatives to the leadership of the National Academies, NSF, the Department of State, and other organizations.
    - The BISO COV chair presented their report virtually to the AC-ISE, which convened May 2018, and OISE responded to those recommendation, June 2018.[2]

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.

[1] OISE COV Report: www.nsf.gov/od/oise/OISECOV-Doc/OISE_COVReport/OISE_FY2018_COV_Final.pdf; Responses: www.nsf.gov/od/oise/OISECOV-Doc/OISE_COVReport/ResponsesToThe2018_OISE_COV_Report.pdf
[2] BISO COV Report: www.nsf.gov/od/oia/activities/cov/oise/2018/OISE_BISO_2018_COV_Report.pdf; Responses: www.nsf.gov/od/oise/OISECOV-Doc/BISOCOV/OISE_Response%20to%202018_BISO%20COV%20Report.pdf

People Involved in OISE Activities

Number of People Involved in OISE Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	270	-	250
Other Professionals	58	-	50
Postdoctoral Associates	23	-	20
Graduate Students	139	-	120
Undergraduate Students	49	-	50
Total Number of People	**539**	**-**	**490**

OFFICE OF POLAR PROGRAMS (OPP) $403,390,000

-$98,330,000 / -19.6%

OPP Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Research	**$119.16**	**-**	**$80.16**	**-$39.00**	**-32.7%**
CAREER	0.48	-	1.10	0.62	128.5%
Long Term Ecological Research (LTER)	3.38	-	3.38	-0.00	-0.1%
Education	**2.02**	**-**	**0.75**	**-1.27**	**-62.9%**
Infrastructure	**364.40**	**-**	**322.48**	**-41.92**	**-11.5%**
Arctic Research Support and Logistics	45.72	-	43.00	-2.72	-5.9%
IceCube Neutrino Observatory (IceCube)	3.50	-	3.50	-0.00	-0.0%
U.S. Antarctic Facilities and Operations[1]	228.16	-	192.14	-36.02	-15.8%
U.S. Antarctic Logistical Support	71.13	-	71.00	-0.13	-0.2%
Geodetic Facility for the Advancement of GEoscience (GAGE)	1.17	-	0.78	-0.39	-33.1%
Seismological Facility for the Advancement of GEoscience (SAGE)	1.84	-	1.22	-0.62	-33.5%
Research and Resources	6.29		4.23	-2.06	-32.7%
Polar Environment, Safety, and Health (PESH)	6.61	-	6.61	0.00	0.1%
Facilities Development and Design Total	**16.14**	**-**	**-**	**-16.14**	**-100.0%**
Antarctic Infrastructure Modernization for Science (Development and Design)	16.14	-	-	-16.14	-100.0%
Total	**$501.72**	**-**	**$403.39**	**-$98.33**	**-19.6%**

[1] FY 2018 Actual includes $42.58 million in additional FY 2018 one-time funding above the requested amount.

About OPP

The Office of Polar Programs is the primary U.S. supporter of fundamental research in the polar regions. In the Arctic, NSF helps coordinate research planning as directed by the Arctic Research Policy Act of 1984, and the NSF Director chairs the Interagency Arctic Research Policy Committee (IARPC) 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 (USAP) 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 research and education and provides support for research infrastructure, such as permanent stations and temporary field camps in the Antarctic and the Arctic, including support for NSF Big Ideas—NNA, WoU, and URoL. OPP's FY 2020 Budget Request is influenced by three key priorities: (1) supporting critical facilities that enable frontier research in the Earth's polar regions; (2) maintaining strong disciplinary programs that provide a base for our investments in cross-disciplinary system science programs; and (3) maintaining U.S. research community activities in polar system science. 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 environmental and ecosystem 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.

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, IARPC's Arctic Research Plan: FY 2017-2021[1], and the World Meteorological Organization's Year of Polar Prediction Implementation Plan[2] 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 National Research Council report *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research*[3] informs science investment priorities. Specifically, in 2018, OPP initiated 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 is jointly supported, including shared logistics, with the National Environment Research Council of the U.K.

Major Investments

- OPP will support science in both polar regions and the major ramp up in the construction tempo of the Antarctic Infrastructure Modernization for Science (AIMS) project. AIMS commenced in 2019 as a MREFC project to address major recommendations by the USAP Blue Ribbon Panel (BRP) report, *More and Better Science in Antarctica through Increased Logistical Effectiveness*.[4] The project is expected to be completed within 10 years from its award.
- In FY 2020, OPP will support research at $80.16 million. OPP will continue to support existing priority commitments, including the Thwaites Glacier program, and Arctic observing that received strong endorsement at the Arctic Science Ministerial, as well as new awards.
- Education activities across OPP will be through Improving Undergraduate STEM Education (IUSE) and Research Experiences for Undergraduates (REU) Sites.
- OPP's investment in Antarctic Facilities and Operations will be $192.14 million. Most of the reduction compared to FY 2018 is due to a one-time investment in 2018 dedicated to replacement of the aging pier at Palmer Station in the Antarctic peninsula with funding above the Request provided from Congress.
- OPP will continue to support the three LTER sites and IceCube at their 2018 levels of funding.
- The AIMS project design will be fully funded by the end of FY 2019; no further design funding is anticipated after that.

OPP provides 46 percent of the federal funding for basic research at academic institutions in the polar sciences.

[1] www.iarpccollaborations.org/uploads/cms/documents/iarpc_arctic_research_plan_2017-2021.pdf
[2] www.polarprediction.net/fileadmin/user_upload/www.polarprediction.net/Home/YOPP/YOPP_Documents/FINAL_WWRP_PPP_YOPP_Plan_28_July_2016_web-1.pdf
[3] www.nap.edu/catalog/21741/a-strategic-vision-for-nsf-investments-in-antarctic-and-southern-ocean-research
[4] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp

OPP Funding for Facilities

OPP Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$234.66**	**-**	**$197.64**	**-$37.02**	**-15.8%**
IceCube Neutrino Observatory (IceCube)	3.50	-	3.50	-	-
U.S. Antarctic Facilities and Operations[1]	228.16	-	192.14	-36.02	-15.8%
Geodetic Facility for the Advancement of GEoscience (GAGE)	1.17	-	0.78	-0.39	-33.1%
Seismological Facility for the Advancement of GEoscience (SAGE)	1.84	-	1.22	-0.62	-33.5%

[1] FY 2018 Actual includes $42.58 million in additional FY 2018 one-time funding above the requested amount.

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

Funding Profile

OPP Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	562	-	700
Number of New Awards	216	-	160
Funding Rate	38%	N/A	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	552	-	670
Number of Research Grants	208	-	135
Funding Rate	38%	N/A	20%
Median Annualized Award Size	$182,943	-	$123,900
Average Annualized Award Size	$225,113	-	$167,000
Average Award Duration, in years	2.8	-	2.5

In general, about 18 percent of the OPP portfolio is available for new research grants. In FY 2020, the number of research grant proposals is expected to increase compared to the FY 2018 Actual and OPP expects to award about 135 research grants.

Program Monitoring and Evaluation

Science and Technology Policy Institute (STPI) Reports:

- In 2018 OPP funded the Science and Technology Institute (STPI) to perform an assessment of polar airlift, *Polar Heavy Airlift: An Analysis of Alternatives*.
- STPI also performed its annual *Survey Analysis of the United States Antarctic Program Logistical Support Services for the 2017–18 Field Season* report.

Committees of Visitors (COV):

- In 2020, COVs will review both Arctic and Antarctic science programs.

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

People Involved in OPP Activities

Number of People Involved in OPP Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	853	-	700
Other Professionals	476	-	400
Postdoctoral Associates	118	-	100
Graduate Students	298	-	200
Undergraduate Students	223	-	200
Total Number of People	**1,968**	**-**	**1,600**

INTEGRATIVE ACTIVITIES (IA) $491,040,000

+$19,990,000 / 4.2%

IA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Convergence Accelerator	-	-	$60.00	$60.00	N/A
Evaluation and Assessment Capability	2.99	-	3.00	0.01	0.4%
EPSCoR	170.59	-	151.23	-19.36	-11.3%
Facility Operation Transition	-	-	10.00	10.00	N/A
Graduate Research Fellowship Program	142.27	-	128.45	-13.82	-9.7%
Growing Convergence Research	5.00	-	16.00	11.00	220.0%
HBCU Excellence in Research[1]	20.15	-	10.00	-10.15	-50.4%
Hispanic-Serving Institutions[2]	15.03	-	-	-15.03	-100.0%
Major Research Instrumentation	100.41	-	65.00	-35.41	-35.3%
Mid-scale Research Infrastructure	-	-	30.00	30.00	N/A
NSF 2026	-	-	6.50	6.50	N/A
NSF INCLUDES[3]	1.90	-	-	-1.90	-100.0%
Planning and Policy Support	3.94	-	2.10	-1.84	-46.7%
Research Investment Communications	3.47	-	3.47	-	-
STC Administration	0.56	-	0.55	-0.01	-1.1%
Science & Technology Policy Institute	4.74	-	4.74	-	-
Total	**$471.05**	**-**	**$491.04**	**$19.99**	**4.2%**

[1] In FY 2017, HBCU-EiR was funded at $10.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($20.15 million).

[2] In FY 2017, the HSI Program was funded at $15.0 million within the Integrative Activities budget. These funds were carried over into FY 2018, and supported awards made in FY 2018 ($15.03 million). EHR is responsible for the management of this program.

[3] NSF INCLUDES funding moves to EHR beginning in FY 2019.

The FY 2020 Budget Request for IA is $491.04 million. This request highlights NSF's continuing emphasis on building capacity across the U.S. research and education enterprise.

About IA

The IA budget is managed by the Office of Integrative Activities (OIA), which consists of three sections: Established Program to Stimulate Competitive Research (EPSCoR), Evaluation and Assessment Capability (EAC), and Integrative Activities.

Through its IA investments, NSF incubates new ideas and communities, supports innovation in research and NSF's own processes, and promotes integration across research and education domains. IA enhances the competitiveness of the Nation's research through activities that build capacity for science and engineering (S&E) and broaden participation in research and education. IA expands NSF's capability to gather and use evidence about the progress and impacts of its programs; and as S&E increasingly evolves towards transdisciplinary, convergence-style research and education, IA catalyzes new cross-cutting programs.

IA provides NSF stewardship for several of NSF's 10 Big Ideas: Growing Convergence Research (GCR), Mid-scale Research Infrastructure, and NSF 2026, as well as the NSF Convergence Accelerator activity. These novel programs support, respectively, innovative team science that crosses traditional domain boundaries, cutting-edge instrumentation, the ideation of broad research themes, and use-inspired, translational research.

IA enhances the capacity of jurisdictions, institutions, and individuals to conduct globally-competitive research. IA's jurisdictional and institutional capacity-based programs include EPSCoR, NSF's Historically Black Colleges and Universities Excellence in Research (HBCU-EiR) program, the Major Research Instrumentation (MRI) program, and Mid-scale Research Infrastructure. The Graduate Research Fellowship Program (GRFP) and the prestigious STEM honorary award program, the Alan T. Waterman award, are designed to grow the capacity of the U.S. research enterprise by investing in emerging talent. IA supports the Science and Technology Centers: Integrative Partnerships (STC) program, a center-scale program that promotes discovery and innovation through collaborative research and knowledge transfer.

FY 2020 Activities

<u>NSF Convergence Accelerator</u>

- Through an organizational structure called the NSF Convergence Accelerator (NSF C-Accel), NSF will continue to pilot a novel, phased approach to identifying, nurturing, and funding use-inspired research, moving ideas from discovery into practice. The first two research topics—(1) workforce skilling and reskilling, and (2) open data sharing—are derived from previous research in two of NSF's 10 Big Ideas, FW-HTF and HDR, which are well aligned with Administration priorities. NSF C-Accel will facilitate convergence and translational activities in these areas, especially by creating and leveraging external partnerships. To select the first cohort of PIs for each topic, a dear colleague letter issued in February 2019, will seek proposals for Phase 1 awards to be made in FY 2019. These awards would support six months of idea refinement, team-building, and preliminary research, culminating in a first round of pitches by spring 2020 for the next phase of support focused on building prototypes, developing experimental designs and other deliverables, as appropriate. For more information about NSF C-Accel, see the narrative in the NSF-Wide Investments chapter.

<u>Evaluation and Assessment Capability</u>

- EAC will continue the systematic and rigorous generation of evidence and facilitate its timely use to strengthen NSF's position as a leader in the evaluation and assessment of investments in S&E research, education, and infrastructure. With the support and advice of an agency-wide steering group of assistant directors and office heads, and a working group of program directors, EAC will:
  - harness high-quality evidence to inform organizational learning and support the achievement of organizational objectives;
  - employ timely recommendations from cost-effective, contracted evaluations; and
  - strengthen NSF's use of evidence in decision-making to achieve its mission.
- EAC will also work with programs to facilitate the development of continuous improvement frameworks, which can be used to guide program implementation and evaluation by identifying milestones and metrics to monitor progress.
- EAC will continue its collaboration with the OIRM Division of Information Systems (DIS) to enhance data quality and access. This collaboration is also making available machine learning tools for portfolio analyses and identifying reviewers for use by NSF staff.

Established Program to Stimulate Competitive Research

- EPSCoR investments assist NSF in its statutory function "to strengthen research and education in the sciences and engineering, including independent research by individuals, throughout the United States, and to avoid undue concentration of such research and education."

Facility Operation Transition

- The Facility Operation Transition is a pilot program that reflects NSF's strategic commitment to successful operations and maintenance (O&M) of new major facilities as well as balancing portfolio funding between facilities and investigator research, both of which were emphasized in the NSB's Congressionally requested 2018 report entitled "Study of Operations and Maintenance Costs for NSF Facilities" (NSB-2018-17).[1] NSB envisioned a more flexible MREFC account as one way to achieve these goals; owing to the challenges that would be introduced by maintaining separate construction and operations funding in the MREFC line, the recommended strategic funding is requested in the R&RA account instead. The funds in this activity will be used to (1) partially support initial O&M of new facilities so that the full O&M costs can be gradually absorbed into the managing division or directorate, and (2) partially support divestment of lower-priority facilities, the full cost of which may significantly impact individual division or directorate funding. A total of $10.0 million is requested in FY 2020 for this program. For more information about Facility Operation Transition, see the discussion in the overview of the Facilities chapter.

Graduate Research Fellowship Program

- GRFP supports the training of tomorrow's leaders in the research community. Funding for GRFP is evenly split between IA and EHR. NSF's FY 2020 GRFP funding will support 1,600 new fellows. Information on recent evaluations of GRFP may be found in the Major Graduate STEM Education narrative in the NSF-Wide Investments chapter.

Growing Convergence Research

- The GCR activity, as one of the enabling Big Ideas, supports basic research on novel, challenging, transdisciplinary questions. The unifying characteristics of these undertakings are that: (a) if successfully answered, they are likely to have a large impact, either on fundamental understanding in S&E or on our ability to meet pressing societal challenges, or both; and (b) they require the integration of knowledge, tools, and ways of thinking from multiple disciplines. GCR also aims to grow the next generation of convergence researchers. In FY 2020, GCR investments will support ten to twelve exploratory research collaborations and up to four capacity-building activities. For more information about GCR, see the narrative in the NSF-Wide Investments chapter.

Historically Black Colleges and Universities—Excellence in Research

- The HBCU-EiR program focuses on improving the research capacity and competitiveness of HBCUs by providing dedicated support for research opportunities at these institutions. IA will fund approximately 12 to 20 HBCU-EiR research grants awarded by NSF's S&E directorates.

Major Research Instrumentation

- MRI will continue to invest in advanced shared-use instrumentation at academic and other non-profit research organizations. The MRI request will enable support for an estimated 130 new awards for instrument development and acquisition across all of NSF's science and engineering research domains. MRI investments also contribute to research-intensive learning environments that promote the development of a diverse S&E workforce and facilitate partnerships between academia and the private sector.

[1] National Science Board, Study of Operations and Maintenance Costs for NSF Facilities (NSB-2018-17), May 2018, www.nsf.gov/pubs/2018/nsb201817/nsb201817.pdf.

Mid-scale Research Infrastructure – Track 1 (Mid-scale RI-1)

- The Mid-scale RI-1 activity funded through the IA budget within the R&RA account is one component of NSF's Mid-scale Research Infrastructure Big Idea. Mid-scale RI-1 investments support: (1) research infrastructure between approximately $6.0 million and $20.0 million, significantly advancing the Nation's research capabilities and serving to maintain U.S. leadership in global S&E; and (2) the design of future research infrastructure projects. For more information about NSF's Mid-scale Research Infrastructure investments, see the narrative in the NSF-Wide Investments chapter.

NSF 2026

- The NSF 2026 Big Idea, named in recognition and celebration of the Nation's 250th anniversary, supports bold research agendas that are large in scope, innovative in character, originate outside any particular discipline and require a long-term focus. Grand challenge initiatives that require an investment horizon of approximately ten years will be identified through an "Idea Machine," which invites broad community input through crowdsourcing, expert panels, and other mechanisms. In FY 2020, NSF 2026 will support workshops, Research Coordination Networks, and EArly-concept Grants for Exploratory Research (EAGERs) that engage the research community in refining and exploring the high-risk, high-reward research themes identified by the FY 2019 NSF Idea Machine. For more information about NSF 2026, see the narrative in the NSF-Wide Investments chapter.

NSF INCLUDES

Beginning in FY 2019, NSF INCLUDES funding will be provided through EHR, which is the steward for this NSF Big Idea. For more information about FY 2020 NSF INCLUDES activities see the narrative in the NSF-Wide Investments chapter.

Planning and Policy Support (PPS)

- The PPS program supports investments in activities, such as workshops, conferences, and long-term planning exercises, focused on emerging themes and agency innovations. PPS includes funding for Proposal Management Efficiencies, which comprise activities such as the NSF biennial survey and studies of NSF's merit review process. PPS supports the costs associated with the Alan T. Waterman award, the United States' highest honorary award for early career scientists and engineers, the National Science Board's Vannevar Bush Award and Public Service Award, and the National Medal of Science. It also supports summer science internship programs that target STEM students from underrepresented groups. PPS provides funding to the National Academies of Science, Engineering, and Medicine (the National Academies) for the Committee on Science, Engineering, Medicine, and Public Policy (CoSEMPuP),[2] as well as studies, workshops, and letter reports that have a scope that spans multiple research domains.

Research Investment Communications (RIC)

- RIC will continue its investment in 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 STEM readily available and easily understandable to everyone. In FY 2020, 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.

Science and Technology Centers: Integrative Partnerships Program

- STC Administration supports post-award management of STC awards, including site visits by review teams. Additionally, FY 2020 funding will support the management of the proposal competition that will determine the new STC cohort that is expected to start in FY 2021.

[2] CoSEMPuP webpage (http://sites.nationalacademies.org/pga/cosepup/index.htm).

Science and Technology Policy Institutes (STPI)

- STPI is a Federally Funded Research and Development Center sponsored by NSF on behalf of the White House Office of Science and Technology Policy (OSTP). STPI provides analysis of significant domestic and international science and technology policies and developments for OSTP and other federal agencies.

Program Monitoring and Evaluation

Evaluation and Assessment Capability Activities

Ongoing projects include:

- *Intergovernmental Personnel Act (IPA).* In FY 2017, NSF began piloting a requirement that all institutions provide a minimum of ten percent cost share for every IPA agreement. In parallel, EAC has been conducting a study of this pilot. The pilot and the study have continued into a second year with the results of the study expected later in FY 2019. This study is being conducted in collaboration with NSF OIRM.
- *Graduate Research Fellowship Program (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 is expected to be in place in FY 2020. This study is co-funded with EHR.
- *Research Experience for Undergraduates (REU).* The primary purpose of this effort is to design, build, pilot, test, and analyze options for a web-based, longitudinal data collection system for following the career trajectories of REU Site participants. This data collection effort will lay the groundwork for future analyses of participant outcomes. In FY 2018, this study was expanded to include International Research Experiences for Students (IRES) in collaboration with OISE. Results are anticipated in FY 2019. This study is co-funded with EHR and OISE.
- *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 of all Launch Pilots, Alliances, and Coordination Hub projects. Results from this developmental phase of the project are anticipated in FY 2019. This study is co-funded with EHR, CISE, GEO, and MPS.
- *I-Corps™ Teams Program.* This longitudinal evaluation of I-Corps™ teams focuses on how the program affects the participants 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. Data collection completed in FY 2018. The preparation of the project report is underway, and results are anticipated in FY 2019. This study is co-funded with ENG.
- *SaTC.* This study builds on STPI findings from a review of historical data from early investments in cybersecurity core programs from 2008 to 2011. The primary emphasis of this evaluation is on data from the inception in FY 2012 of SaTC, an NSF cross-cutting program, to the present. An understanding of how and in what ways SaTC makes collective progress toward its talent development goals and objectives will inform the use of these findings to refine existing and future SaTC program level activities. Data collection has begun, and initial findings will be presented to NSF in spring 2019. Final results are anticipated before the end of FY 2020. This study is co-funded with CISE.
- *Centers for Chemical Innovation (CCI).* The purpose of this comprehensive assessment is to understand how the CCI program achieves its stated goals. Of particular interest is an understanding of the nature of collaborative practices in the centers. The results of this study will be used to communicate how the program functions and to strengthen its design and operation. Preliminary reporting of findings from analyses of agency administrative data and publication records is underway. Results are anticipated in FY 2019. This study is co-funded with MPS.
- *EPSCoR.* The purpose of this evaluation is two-fold: (1) to develop a flexible framework to explore, describe, and measure research competitiveness in relation to the unique contexts of each EPSCoR jurisdiction; 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 EPSCoR program-level activities. The final project planning activities have been completed and the study team is finalizing the framework and proposed data analyses. Results are anticipated in FY 2020. This study is co-funded with EPSCoR.

In 2018, two evaluations were completed, and their reports were submitted to NSF:

- *Geoscience Education (GeoEd).* This evaluation describes the extent to which the GeoEd portfolio is contributing to and progressing toward the achievement of program goals. The purpose of this evaluation was three-fold: (1) to develop a flexible framework to define, measure, and explore value and outcomes; (2) to provide evidence of the range, synergies, and variability of factors contributing to impact over time; and (3) to strengthen the practice of evaluative inquiry for program improvement among GeoEd decision-makers and stakeholders. The results are being used to develop a strategic plan. The evaluation concluded in August 2018 with a final report and presentation delivered to internal NSF stakeholders. EAC staff facilitated a review of the report and incorporation of findings in a strategic visioning process that concludes in March 2019. This study was co-funded with GEO.
- *Science, Engineering, and Education for Sustainability (SEES).* This evaluation examined the extent to which the SEES portfolio achieved its goals as measured by: (1) the creation of new knowledge and conceptual understanding; (2) the existence and enhancement of productive connections between and among researchers across disciplines; and (3) the creation of a workforce able to handle future sustainability challenges. The study, which compares SEES projects with non-SEES projects, found that the SEES projects were successful in bringing together multiple perspectives and developed more extensive principal investigator (PI) networks. SEES PIs found that dissemination and outreach also yielded new research ideas.

<u>Evaluation and Assessment Capability Related Activities</u>

- In the spring and early summer of 2018, EAC participated in NSF's Strategic Review (SR) process, in which federal agencies assess their progress towards on their strategic objectives.
  - EAC staff co-lead one SR, on developing a Learning agenda for NSF INCLUDES. Learning agendas are a systematic approach to engaging stakeholders in asking questions with answers that yield evidence to inform decision-making and policy action to enhance performance of programs and other organizational units, including the agency as a whole. The NSF INCLUDES Learning Agenda Strategic Review laid the groundwork for the development of a learning agenda on which EAC began working at the start of FY 2019, in collaboration with EHR.
  - The other four SRs covered the four pillars of Renewing NSF and were facilitated by EAC. In FY 2019, EAC will continue to support the implementation of Renewing NSF by leading the monitoring and assessment of progress.
- FY 2019 EAC related activities include the ongoing projects described above. In addition:
  - EAC will focus on gathering evidence to describe the implementation of two of NSF's 10 Big Ideas, NSF INCLUDES and GCR, as well as NSF C-Accel. The evidence thus generated will be used to inform day-to-day operations and performance improvement as these activities mature. EAC will also continue to monitor the progress of Renewing NSF.
  - EAC, in collaboration with NSF's Office of Diversity and Inclusion, has begun to investigate the requirements for a potential monitoring system to understand the effects of NSF's policy on sexual harassment, announced in September 2018.
- In FY 2020, the GRFP, SaTC, and EPSCoR projects will continue, as will the work focused on NSF's 10 Big Ideas and NSF C-Accel. EAC will also lead NSF's response to the forthcoming OMB guidance and enable implementation of the requirements of the Foundations for Evidence-Based Policymaking Act of 2018 (FEBP, P.L. 115-435). In FY 2020, EAC will engage in new collaborative evaluation projects in accordance with NSF's priorities.

Workshops and Reports:

- In FY 2018, with the National Institutes of Health and other agencies, NSF co-funded studies by the National Academies on:
  - The role of inducement prizes in spurring innovation. A public workshop on the role of inducement prizes is anticipated in spring 2019, with release of a final report in early 2020;
  - The sexual harassment of women in academic sciences, engineering and medicine. A report entitled "Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine" was released by the National Academies in June 2018; and
  - How to address the under-representation of women in science, engineering and medicine. A symposium highlighting evidence-based interventions for addressing the underrepresentation of women in science, engineering, and medicine will be held in March 2019.
- In FY 2017 and FY 2018, NSF funded a National Academies study of reproducibility and replicability in science. The release of that study report is anticipated in April 2019. NSF also funded a workshop on environmental and security science, held in October 2018, with a report anticipated by summer 2019.

Committees of Visitors (COV):

- In 2018, none of the IA programs held a COV.
- In 2019, none of the IA programs will hold a COV.
- In 2020, COVs will review the EPSCoR and MRI programs.

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

ESTABLISHED PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCOR) **$151,230,000**
-$19,360,000 / -11.3%

EPSCoR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$170.59**	**-**	**$151.23**	**-$19.36**	**-11.3%**
Research Infrastructure Improvement (RII)	142.20	-	125.94	-16.26	-11.4%
Co-Funding	27.59	-	24.50	-3.09	-11.2%
Outreach and Workshops	0.79	-	0.79	-	-

About EPSCoR

EPSCoR assists NSF in its statutory function "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education." EPSCoR seeks to advance excellence in science and engineering research and education, enhancing the competitiveness of EPSCoR jurisdictions in the science and engineering domains supported by NSF.

In general, about 12 percent of the EPSCoR portfolio is available to support new research grants. The remaining 88 percent supports grants made in prior years.

EPSCoR uses three strategic investment tools: Research Infrastructure Improvement (RII) awards, Co-Funding, and Outreach/Workshops.

Research Infrastructure Improvement (RII)

- RII awards will continue to 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 effect 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 invest in workforce development, increase the participation of underrepresented groups in STEM, enable broader regional and topical collaborations among jurisdictions, and facilitate the enhancement of discovery, learning, and economic development of EPSCoR jurisdictions.

Co-Funding

- 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, including crosscutting initiatives.

Outreach and Workshops

- The Outreach and Workshops 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.

People Involved in EPSCoR Activities

Number of People Involved in EPSCoR Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	573	-	600
Other Professionals	184	-	200
Postdoctoral Associates	103	-	100
Graduate Students	496	-	500
Undergraduate Students	462	-	600
K-12 Teachers	4,545	-	4,100
K-12 Students	115,331	-	102,200
Total Number of People	**121,694**	**-**	**108,300**

UNITED STATES ARCTIC RESEARCH COMMISSION (USARC) **$1,524,000**
+$90,5000 / 6.3%

USARC Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$1.43	**-**	**$1.52**	**$0.09**	**6.3%**

About USARC

USARC was created by the Arctic Research and Policy Act of 1984, (as amended, P. L. 101-609), to establish the national policy, priorities, and goals necessary to construct a federal program plan for basic and applied Arctic scientific research. USARC advises the Interagency Arctic Research Policy Committee 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 and local 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.

USARC is requesting $1.524 million, $90,500 above the FY 2018 Actual. In FY 2020, new leases will be established for both USARC offices (in Arlington, VA, and in Anchorage, AK) by the General Services Administration. The FY 2020 Request provides funds to advance Arctic research, and to recommend Arctic research policy that is consistent with the Administration's *FY 2020 Administrative Research and Development Budget Priorities* (M-18-22).

The FY 2020 Request will support three FTE funded at USARC. In addition, the FY 2020 Request supports one full-time contractor and four part-time contractors. A total of seven compensated personnel are authorized per P.L. 101-609. The seven Commissioners may also receive up to 90 days of salary per year, at the Executive Schedule Level IV.

EDUCATION AND HUMAN RESOURCES (EHR)

$823,470,000
-$80,400,000 / -8.9%

EHR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Division of Research on Learning in Formal and Informal Settings (DRL)	$228.22	-	-	$181.72	-$46.50	-20.4%
Division of Undergraduate Education (DUE)	254.65	-	-	219.39	-35.26	-13.8%
Division of Human Resource Development (HRD)	162.66	-	-	178.30	15.64	9.6%
Division of Graduate Education (DGE)	258.34	-	-	244.06	-$14.28	-5.5%
Total	**$903.87**	**$902.00**	**$910.00**	**$823.47**	**-$80.40**	**-8.9%**

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

About EHR

EHR's role in accomplishing NSF's mission is to advance excellence in U.S. STEM education at all levels and in all settings to support the development of a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians and educators and a well-informed citizenry that have access to the ideas and tools of science and engineering. To accomplish this, EHR invests in the development of people and knowledge.

Progress in STEM depends on the education of *discoverers*—innovators and future leaders in the Nation's science and engineering (S&E) enterprise. These discoverers are critical members of the STEM and STEM-related workforce, including public and private sector, academic, policy, research, and teaching occupations. The progress of S&E also depends on a public that can take full advantage of STEM-shaped employment opportunities of the future, and values and participates in STEM (e.g., through formal and informal education, public participation in scientific research, and civic engagement). Importantly, 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.

EHR plays a vital role in attaining these objectives. EHR is a leader in federal efforts to: prepare the STEM workforce for the future; remove barriers to participation in STEM careers; increase diversity, equity, and inclusion in STEM; and promote excellence in STEM education for all learners across the life-course. EHR is responsible for careful stewardship of public funds that support the development of the Nation's human capital in STEM. EHR awards provide funds that support traineeships, fellowships, research experiences, reskilling and upskilling professional development, and a wide range of institutional capacity building programs. Collectively, these programs educate, train, and support discoverers; engage citizen scientists; and foster a well-informed, STEM-literate citizenry prepared to handle rapid technological change and pursue STEM careers.

Uniquely in the federal context, EHR programs also fund the *discoveries*—the crucial foundational research and the design and implementation studies—that underpin these STEM human capital development initiatives. Just as NSF's R&RA directorates are dedicated to funding basic research that accelerates progress in S&E, EHR supports early-stage, exploratory research that enables improvements in STEM education, learning, and assessment. Each decade brings new challenges, new learnings, and new opportunities to enhance STEM learning—and as scientists and engineers make new discoveries, education must adapt to the new skills and knowledge necessary for our nation to stay on the cutting-edge of scientific advances.

Knowledge arising from EHR's research portfolio informs EHR's human capital initiatives and a suite of NSF-wide investments in undergraduate and graduate STEM education and broadening participation. Importantly, results, data, and innovations arising from EHR-supported research are also available to catalyze discoveries and inform investments at scale made by other agencies, organizations, and the private sector. In the preK-12 realm, for example, EHR invests in research that yields focused, catalytic contributions to push the frontiers of effective learning and practice in formal education and informal learning environments. In the area of professional workforce development, EHR invests in research that can advance and accelerate efforts to reskill and upskill the workforce in areas where STEM disciplines and skills converge. Across learner populations, EHR invests in research to develop the theories and provide vital evidence to inform STEM education innovation and improvement. Collectively, EHR's research investments provide the knowledge capital that underpins a broad spectrum of STEM education initiatives—at NSF, federally, in schools and institutions of higher education, online, and in libraries, museums, and other learning contexts across the country.

EHR's research and human capital investments are coordinated across three thematic areas:

- STEM learning and learning environments,
- broadening participation and institutional capacity, and
- STEM professional workforce development.

These themes are consistent with the three aspirational goals highlighted in the federal government's five-year strategic plan for STEM education, *Charting a Course for Success: America's Strategy for STEM Education*: (1) build strong foundations for STEM literacy; (2) increase diversity, equity, and inclusion in STEM; and (3) prepare the STEM workforce for the future.[1] EHR's thematic areas also provide a framework for coordinating EHR's contributions to NSF's 10 Big Ideas and identifying opportunities to deepen and strengthen synergies with the R&RA directorates.

EHR's FY 2020 Budget Request is shaped by support for several of NSF's 10 Big Ideas. To increase diversity, equity and inclusion in STEM, EHR will steward the NSF INCLUDES Big Idea, contributing basic, design and development, and implementation research. EHR will also coordinate the participation of other federal agencies and private sector partners in NSF INCLUDES. EHR's stewardship of NSF INCLUDES will incubate and widely disseminate successful models of engaging and retaining populations traditionally underserved in the STEM disciplines—in particular, minorities, women, and persons with disabilities.

In addition to NSF INCLUDES, EHR will contribute to the HDR, FW-HTF, and NNA Big Ideas in FY 2020. As part of the HDR Big Idea, EHR will collaborate with other directorates and offices to make essential contributions to research on how to create and nurture a 21st century data-capable workforce. Through investments from the Division of Undergraduate Education, EHR will continue advances in curriculum and pedagogy of data science. EHR investments will spur discoveries to foster lifelong learning and pervasive learning through technology as part of the FW-HTF Big Idea. Learners must be empowered to take advantage of the transformations to society and work that have resulted from new technologies. EHR will foster discoveries to expand digital platforms and develop new cyberlearning systems to engage all learners in the STEM skills necessary for the workforce of the future. Lastly, EHR will participate in the NNA Big Idea which introduces questions about how to train the next generation of scientists to work at

[1] www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

the intersection of social science, natural science, engineering, and economics, creating a laboratory for learning research in convergent spaces. EHR's investments will contribute to the development of a new generation of convergent thinkers and continue to advance innovative ways to engage the public in the research developed through the NNA Big Idea. For more information on NSF's 10 Big Ideas and other priorities, see the NSF-Wide Investments chapter.

EHR staff continue to provide cross-agency leadership to the Federal Coordination in STEM Education Task Force and the associated interagency working groups. 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
GRFP	$142.58	-	$128.45	-$14.13	-9.9%
NRT[1]	33.11	-	49.53	16.42	49.6%
SaTC	55.09	-	55.09	-	-
UtB	11.99	-	7.00	-4.99	-41.6%
BRAIN Initiative	*2.00*	-	*2.00*	-	-
NSFs Big Ideas					
NSF INCLUDES[2]	*5.47*	-	*20.00*	*14.53*	*265.6%*

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

[1] Total FY 2018 Actual funding for NRT is $53.85 million with $20.74 million contributed from the R&RA account. In FY 2020, all funding for NRT resides in the EHR account. For more information on NRT, see the Major STEM Graduate Education narrative in the NSF-wide Investments chapter.

[2] Total FY 2018 Actual funding for NSF INCLUDES is $17.95 million with $12.48 million contributed from the R&RA account. In FY 2020, all funding for NSF INCLUDES resides in the EHR account. For more information, see the NSF INCLUDES narrative in the NSF-wide Investments chapter.

For more information on programs that support EHR Major Investments, see EHR's division sections.

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, ~~$873,370,000,~~ $823,470,000, to remain available until September 30, ~~2020.~~2021.

Education and Human Resources
FY 2020 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 2018 Appropriation	$902.00	$7.66	-$14.26	$8.47	-	$903.87
FY 2019 Annualized CR	902.00	14.26				916.26
FY 2019 Enacted	910.00					910.00
FY 2020 Total Request	823.47					823.47
$ Change from FY 2019 Enacted						-$86.53
% Change from FY 2019 Enacted						-9.5%

Totals exclude reimbursable amounts.

Explanation of Carryover

Within the Education and Human Resources (EHR) account, $14.27 million (including $9,347 in reimbursable funds) was carried over into FY 2019.

Excellence Awards in Science and Engineering

- Amount: $3.63 million
- Reason: These carryover funds will be used to recognize recipients of the Presidential Awards for Excellence in Mathematics and Science Teaching and recipients of the Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring.
- Obligation: Anticipated FY 2019 Quarter 2

The remaining $10.63 million of unallotted no-year funds will be used for awards supporting STEM teacher education associated with the Robert Noyce Teacher Scholarship Program and the EHR Core Research program.

Funding Profile

EHR Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	4,161	-	4,300
Number of New Awards	893	-	770
Funding Rate	21%	N/A	18%
Statistics for Research Grants:			
Number of Research Grant Proposals	3,106	-	3,140
Number of Research Grants	472	-	460
Funding Rate	15%	N/A	15%
Median Annualized Award Size	$295,992	-	$287,100
Average Annualized Award Size	$345,312	-	$332,900
Average Award Duration, in years	3.3	-	3.3

Program Monitoring and Evaluation

EHR continues its strong emphasis on evidence-based decision making, as well as its commitment to generating robust evidence to inform the development, management, and assessment of directorate programs and portfolios of investment. EHR's evaluation priorities include ensuring the efficient use of available administrative data assets and coordinating evidence-building and use across NSF's STEM education, workforce, and broadening participation programs.

External Program Evaluations and Studies:

- In FY 2018, EHR initiated a third-party evaluation of the ADVANCE program.
- In February 2019, EHR supported a workshop entitled *Essential questions and measures: Assessing institutional transformation of undergraduate STEM education* the results of which will inform future plans to evaluate the IUSE program.
- EHR tentatively plans to complete an assessment of the Graduate Research Internship Program (GRIP) in FY 2019. EHR expects insights from this assessment will inform future evaluations of related initiatives (e.g., the INTERN supplemental funding opportunity that since FY 2018 has supported non-academic research internships to improve graduate student preparedness for the STEM workforce).
- In November 2018, EHR completed a collaborative project with the Institute of Education Sciences (IES) to update the *Common Guidelines for Education Research and Development*[2] (jointly released in 2013). A supplement, the *Companion Guidelines on Replication & Reproducibility in Education Research*, was issued in November 2018 to "highlight the importance" of reproducibility and replication studies in education research and "provide cross-agency guidance on the steps investigators are encouraged to take to promote corroboration, ensure the integrity of education research, and extend the evidence base."[3]
- In FY 2020, EHR will complete a systematic plan for addressing priority questions relevant to the directorate's STEM human capital development programs and continue to review existing data assets and assess how they can be leveraged for monitoring and evaluative purposes.
- In FY 2020 and beyond, EHR-based infrastructure and processes will continue to be developed in collaboration with the NSF Evaluation and Assessment Capability, as appropriate. Additionally, EHR experts in evaluation will continue to collaborate with 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, building collaborative expertise for STEM education evaluation across agencies, and accomplishing the objectives for operating with transparency and accountability set-out in the federal government's five-year strategic plan for STEM education, *Charting a Course for Success: America's Strategy for STEM Education*.

EHR will employ evidence from these and other ongoing evaluations and monitoring initiatives to inform future EHR-program decision-making.

Committees of Visitors (COV):

In 2015, EHR began a transition from COVs focusing on individual programs to division-wide COVs that comprehensively examine all programs in the relevant division. All four EHR divisions have now transitioned to this new model.

- In late 2018, COVs reviewed the Division of Graduate Education (DGE) and the Division of Undergraduate Education (DUE). Those COVs are expected to present their reports to the EHR Advisory Committee at its spring 2019 meeting.
- In fall 2019, a COV will review the Division of Research on Learning (DRL).

[2] www.nsf.gov/pubs/2013/nsf13126/nsf13126.pdf
[3] www.nsf.gov/pubs/2019/nsf19022/nsf19022.pdf?WT.mc_id=USNSF_179

- In 2020, a COV will review the Division of Human Resource Development (HRD).

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.

People Involved in EHR Activities

Number of People Involved in EHR Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	6,654	-	6,000
Other Professionals	2,421	-	2,100
Postdoctoral Associates	316	-	300
Graduate Students	11,200	-	10,200
Undergraduate Students	16,500	-	15,100
K-12 Teachers	37,400	-	34,100
K-12 Students	84,600	-	77,200
Total Number of People	**159,091**	**-**	**145,000**

DIVISION OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS (DRL)

$181,720,000
-$46,500,000 / -20.4%

DRL Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual: Amount	Change over FY 2018 Actual: Percent
Total	**$228.22**	**-**	**$181.72**	**-$46.50**	**-20.4%**
Learning and Learning Environments	**25.63**	**-**	**27.78**	**2.15**	**8.4%**
Computer Science for All (CSforAll)[1]	*[10.00]*	-	10.00	-	-
EHR Core Research (ECR): STEM Learning	25.63	-	17.78	-7.85	-30.6%
Broadening Participation & Institutional Capacity	**150.72**	**-**	**153.94**	**3.22**	**2.1%**
Advancing Informal STEM Learning (AISL)	62.13	-	58.94	-3.19	-5.1%
Discovery Research PreK-12 (DRK-12)	88.59	-	95.00	6.41	7.2%
STEM Professional Workforce	**51.87**	**-**	**-**	**-51.87**	**-100.0%**
Science, Technology, Engineering, Mathematics + Computing (STEM+C) Partnerships[1]	51.87	-	-	-51.87	-100.0%

[1] In FY 2018, CSforAll was supported as a component of STEM+C. The FY 2018 Actual is shown for comparison purposes only. FY 2020 funding for STEM+C moves to implement CSforAll as a freestanding program and to expand EHR's computer science education portfolio through existing programs.

About DRL

DRL invests in foundational research to advance understanding about teaching and learning in science, technology, engineering, and mathematics. Advances in STEM learning ultimately support individuals who pursue STEM careers, as well as the Nation's future STEM workforce more broadly. The DRL portfolio includes the design, implementation, and study of learning environments, models, and digital platforms intended to enable STEM learning for all students—particularly those who have been underrepresented in STEM—through both formal and informal activities across the STEM ecosystem. DRL's programs inform and support lifelong access to high-quality STEM learning opportunities that will prepare learners for jobs of the future.

FY 2020 priorities for DRL include investing in research and development in the following areas:

- Computer science education, including research on computational thinking and the integration of computing with other STEM disciplines.
- STEM learning and learning environments, broadening participation, workforce, and methodologies for STEM education research.
- Learning in math and science disciplines, as well as where disciplines converge, cutting across the STEM ecosystem including formal (preK-12) and informal settings.
- Research that employ data science (associated with the HDR Big Idea), neuroscience, cyberlearning (associated with the FW-HTF Big Idea), and artificial intelligence methodologies. This work will 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.

- Understanding, measuring, and enhancing socioemotional skills, such as persistence, teamwork, and learning to learn, in the context of STEM education.
- Early childhood STEM learning and building foundations for STEM literacy at the preK-12 level.

FY 2020 Summary

Learning and Learning Environments

- CSforAll will be a free-standing program in FY 2020, and will be supported at $10.0 million in EHR, with an additional $10.0 million in support from CISE. Previously, CSforAll was supported as a component of the STEM+C Partnerships program.
- ECR: STEM Learning is funded at a total of $17.78 million. The resources will support fundamental research (basic research or use-inspired basic research) that advances knowledge on STEM teaching and learning for enduring and cross-cutting issues, addresses urgent national priorities in STEM education, and builds the Nation's capacity to improve STEM teaching and learning.

Broadening Participation in STEM

- Within AISL, $58.94 million will support design, adaptation, implementation, and research on innovative modes of lifelong learning in informal environments, including emphases on broadening participation in STEM, public participation in scientific research, cyberlearning, digital and computational literacy, as well as learning in rural and urban environments.
- DRK-12 is provided $95.0 million for improving STEM achievement of all preK-12 students in math and science disciplines. DRK-12 will support innovative areas such as computer science and engineering education, bolstering a well-prepared teacher workforce and enabling success for preK-12 students in all groups and across diverse educational settings including digital platforms.
- In collaboration with DUE through IUSE and ECR, DRK-12 will invest a total of $7.0 million in research to better understand brain function during learning and to apply findings for the improvement of education. This investment in UtB includes $2.0 million for brain research through the BRAIN Initiative.

STEM Professional Workforce

- The STEM+C Partnerships requested funding level is zero, due to a re-distribution of the major program elements into CSfor All and DRK-12. The STEM+C program conducted a portfolio evaluation in FY 2018, which concluded that a consolidation of NSF’s K-12 computing education programs could strengthen agency-wide efforts. In response to the evaluation, EHR will shift some support for STEM+C Partnerships into implementing CSforAll as a freestanding program and will also increase DRK-12 funding to $95.0 million, which will expand its computer science education portfolio. AISL and DRK-12 will continue to invest in R&D supporting computer science education, including research on computational thinking and the integration of computing with other STEM disciplines.

DIVISION OF UNDERGRADUATE EDUCATION (DUE) **$219,390,000**
-$35,260,000 / -13.8%

DUE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$254.65**	**-**	**$219.39**	**-$35.26**	**-13.8%**
Learning and Learning Environments	**123.89**	**-**	**97.39**	**-26.50**	**-21.4%**
EHR Core Research (ECR): STEM Learning Environments	13.10	-	9.09	-4.01	-30.6%
IUSE: Hispanic Serving Institutions (HSI)	19.82	-	10.00	-9.82	-49.6%
Improving Undergraduate STEM Education	90.98	-	78.30	-12.68	-13.9%
STEM Professional Workforce	**130.75**	**-**	**122.00**	**-8.75**	**-6.7%**
Advanced Technological Education (ATE)	66.05	-	75.00	8.95	13.6%
NSF Innovation Corps (I-Corps™)	0.20	-	-	-0.20	-100.0%
Robert Noyce Teacher Scholarship Program (Noyce)	64.50	-	47.00	-17.50	-27.1%

[1] The FY 2018 HSI funding total of $45.0 million included $15.0 million in FY 2017 carryover funds in IA and $30.0 million in FY 2018 funds in EHR. Within EHR, HSI is co-managed by DUE and HRD. The HSI FY 2020 Request level of $15.0 million will target attracting HSIs not having a funding-track record with NSF while education research and development projects at HSIs will be funded through other EHR programs including IUSE, S-STEM, and ATE.

About DUE

DUE supports excellence in undergraduate STEM education for all students by funding projects that design, develop, and implement high-quality educational experiences, as well as execute the scientific research needed to understand the effectiveness of those experiences. DUE investments promote improved teaching practices across the full range of U.S. higher education: community colleges, four-year colleges, comprehensive public institutions, and research universities. In turn, improved STEM learning opens multiple career pathways and improves employment outcomes for undergraduates. For example, innovative educational programs at community colleges enable students to learn advanced technologies such as additive manufacturing, biotechnology, precision agriculture, nano-optics, or cybersecurity. DUE support also enables STEM majors to enter the K-12 teaching workforce in high-need school districts. Such improvements in STEM education enhance student learning, which supports greater retention and degree attainment rates, thus broadening participation in the future STEM workforce and helping to meet future STEM workforce needs.

FY 2020 priorities for DUE include:

- Increasing understanding of what works in undergraduate education, for whom, and why.
  - DUE will continue to be the main source of support across federal agencies for discipline-based educational research (DBER).[4] DBER applies disciplinary expertise and evidence from the learning sciences to create physical and virtual tools, technologies, and high-impact student experiences that could improve undergraduate STEM learning. DBER then uses R&D strategies to iteratively improve these results. Through such design-research cycles, DBER has the potential to improve STEM learning across the Nation, and across all STEM disciplines.

[4] www.nap.edu/catalog/13362/discipline-based-education-research-understanding-and-improving-learning-in-undergraduate

- Support and influence systemic efforts to improve undergraduate STEM education.
  - DUE will expand existing efforts or develop new funding strategies to support transformation at departmental, institutional, and national scales. This effort will include increased support for research on institutional transformation best practices.
  - Given the increasing role of data science in today's STEM and other enterprises, DUE will examine current investments in data science education. Based upon that analysis, new funding opportunities may emerge or existing programs expanded, such as investments in HDR and the FW-HTF Big Ideas.
  - DUE will examine how to better integrate STEM learning activities with activities that develop students' skills, work habits, and character. This effort will contribute to developing the next generation of researchers who will study STEM and undergraduate STEM education.
  - To ensure the continual responsiveness of the DUE "flagship program" to changing needs, DUE will implement an IUSE: EHR program evaluation.
- Increase the number and diversity of STEM workers and STEM-knowledgeable workers.
  - DUE will continue to support the preparation of future K-12 teachers and highly skilled technicians in advanced technology industries. To broaden participation, additional attention will be placed on attracting proposals to IUSE: EHR from investigators at minority-serving community colleges, and/or from two- and four- year institutions with prior funding from HBCU-UP and TCUP.
  - DUE programs will emphasize R&D 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.
- Spur research on STEM learning and learning environments, broadening participation, workforce, and methodologies for STEM education research.

FY 2020 Summary

<u>Learning and Learning Environments</u>

- ECR: STEM Learning Environments is funded at a total of $9.09 million. With these funds DUE will continue to support foundational research on STEM undergraduate education, including on-line learning and other innovative approaches supporting active learning.
- DUE's IUSE: HSI program budget remains at the agency-wide level of $10.0 million. Together with HRD's $5.0 million, DUE will continue to support R&D to improve STEM learning in institutions with a high proportion of Hispanic students.
- IUSE: EHR is provided $78.30 million to support scaling evidence-based practices to departmental, institutional, or national levels; advancing the knowledge base for institutional transformation and evidence-based teaching practices; 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. For more information see the IUSE narrative in the NSF-Wide Investments chapter.

<u>STEM Professional Workforce</u>

- ATE, funded at $75.0 million, will support R&D on effective preparation of the skilled technical workforce, including technicians in advanced technological industries.
- The I-Corps™ requested funding level is zero. In FY 2020, EHR will not be investing in I-Corps™ due to low business ventures from the initial pilot cohorts on STEM education R&D.
- Noyce is provided $47.0 million and will invest in teacher preparation in STEM.

DIVISION OF HUMAN RESOURCE DEVELOPMENT (HRD) **$178,300,000** **+$15,640,000 / 9.6%**

HRD Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$162.66**	**-**	**$178.30**	**$15.64**	**9.6%**
Learning and Learning Environments	**58.54**	**-**	**71.74**	**13.20**	**22.5%**
ADVANCE[1]	1.53	-	18.00	16.47	1076.5%
Alliances for Graduate Education and the Professoriate (AGEP)	8.00	-	7.54	-0.46	-5.8%
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)	34.92	-	33.00	-1.92	-5.5%
INSPIRE	0.09	-	-	-0.09	-100.0%
Tribal Colleges and Universities Program (TCUP)	14.00	-	13.20	-0.80	-5.7%
Broadening Participation & Institutional Capacity	**74.37**	**-**	**79.93**	**5.56**	**7.5%**
EHR Core Research (ECR): Broadening Participation and Institutional Capacity in STEM	12.88	-	8.93	-3.95	-30.7%
IUSE: Hispanic Serving Institutions (HSI) Program[2]	10.00	-	5.00	-5.00	-50.0%
Big Idea: NSF INCLUDES[3]	5.47	-	20.00	14.53	265.6%
Louis Stokes Alliances for Minority Participation (LSAMP)	46.02	-	46.00	-0.02	-0.0%
STEM Professional Workforce	**29.75**	**-**	**26.63**	**-3.12**	**-10.5%**
Centers for Research Excellence in Science and Technology (CREST)	24.01	-	22.63	-1.38	-5.7%
Excellence Awards in Science and Engineering (EASE)	5.74	-	4.00	-1.74	-30.3%

[1] Total FY 2018 Actual funding for ADVANCE is $18.0 million with $16.47 million contributed from the R&RA account. In FY 2020, all funding for ADVANCE resides in the EHR account.

[2] The FY 2018 HSI funding total of $45.0 million included $15.0 million in FY 2017 carryover funds in IA and $30.0 million in FY 2018 funds in EHR. Within EHR, HSI is co-managed by DUE and HRD. The HSI FY 2020 Request level of $15.0 million will target attracting HSIs not having a funding-track record with NSF while education research and development projects at HSIs will be funded through other EHR programs including IUSE, S-STEM, and ATE.

[3] Total FY 2018 Actual funding for NSF INCLUDES is $17.95 million with $12.48 million contributed from the R&RA account. In FY 2020, all funding for NSF INCLUDES resides in the EHR account.

About HRD

HRD's mission is to create and grow a vibrant and diverse U.S. STEM workforce by supporting the inclusion and broadening participation of underrepresented individuals in STEM and the institutions that serve them. HRD supports the development of and research on effective mechanisms and models for broadening participation, institutional transformation through institutional policies and practices, capacity building for STEM and STEM education research at minority-serving institutions, and faculty and student development.

FY 2020 priorities for HRD include:

- Continue to strengthen NSF-wide activities focusing on inclusion and broadening participation for all groups in STEM.
- Collaborate with all NSF directorates to enhance the research capability at HBCUs through the HBCU Excellence in Research (EiR) initiative.

- Encourage institutional collaboration with other federal agencies, state governments, national laboratories, private sector research labs, and K-12 schools, districts and state agencies to advance knowledge and education on research of significance to the Nation.
- Support programs with objectives to broaden participation and increase institutional capacity in STEM through better retention of students traditionally underserved in STEM.
- Continue to identify and recognize outstanding K-12 STEM educators and mentors and support their professional development in partnership with the Office of Science and Technology Policy.

FY 2020 Summary

Learning and Learning Environments

- ADVANCE remains at the agency-wide level of $18.0 million with all funding resources residing in EHR. In FY 2020, EHR will continue to support institutional transformation and faculty development, while also assessing the sustainability of ADVANCE activities, practices and strategies.
- AGEP is provided a total of $7.54 million to support innovative models of doctoral education and faculty advancement for historically underrepresented minorities (URMs) in STEM and/or STEM education research fields. AGEP will continue to work with GRFP and NRT to advance knowledge and practices that improve the participation, transitions, and advancement of URMs in the STEM academy.
- HBCU-UP FY 2020 resources total $33.0 million. This funding will continue to support institutional transformation efforts through research by HBCU STEM faculty that will also enhance the academic and research experiences of students, and thereby increase the number of students completing STEM degrees. HBCU-UP will continue to work with other NSF directorates to enhance the STEM research capacity of the HBCUs.
- TCUP FY 2020 funding totals $13.20 million and will support the design and implementation of comprehensive institutional improvements in STEM instruction and research capacity at Tribal Colleges and Universities, as well as Alaska Native- and Native Hawaiian-serving institutions of higher education.

Broadening Participation in STEM

- ECR: Broadening Participation and Institutional Capacity is funded at a total of $8.93 million. The resources will support fundamental research that advances knowledge in broadening participation in STEM fields.
- IUSE: HSI program will be jointly managed by HRD and DUE. FY 2020 funds from HRD are $5.0 million and will support projects that enhance undergraduate STEM education through research, partnerships, and knowledge development.
- NSF INCLUDES remains at the agency-wide level of $20.0 million with all funding resources residing in EHR. Funds will support incubation and dissemination of models of engaging and retaining populations traditionally underserved in the STEM disciplines. For more information, see the NSF INCLUDES narrative in the NSF-wide Investments chapter.
- LSAMP funding remains at $46.0 million FY 2020. This funding will continue its focus on broadening participation in STEM research and evaluation to expand knowledge about effective strategies for student recruitment, retention, and persistence in STEM programs.

STEM Professional Workforce

- CREST is provided $22.63 million to support new CREST centers and continuation of the Postdoctoral Research Fellowship track introduced in FY 2016. This track increases collaborations across the centers and builds research capacity at minority serving institutions.
- EASE funding totals $4.0 million. In FY 2020, collaborative efforts among the EASE, Noyce, and DRK-12 programs will support the professional development of preK-12 teachers by piloting models for teacher leadership.

DIVISION OF GRADUATE EDUCATION (DGE) **$244,060,000**
-$14,280,000 / -5.5%

DGE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$258.34**	**-**	**$244.06**	**-$14.28**	**-5.5%**
Learning and Learning Environments	**7.57**	**-**	**-**	**-7.57**	**-100%**
Project and Program Evaluation (PPE)	7.57	-	-	-7.57	-100.0%
STEM Professional Workforce	**250.77**	**-**	**244.06**	**-6.71**	**-2.7%**
CyberCorps®: Scholarship for Service (SFS)	55.09	-	55.09	-	-
EHR Core Research (ECR): STEM Professional Workforce Preparation	20.00	-	10.99	-9.01	-45.0%
Graduate Research Fellowship Program (GRFP)	142.58	-	128.45	-14.13	-9.9%
NSF Research Traineeship (NRT)[1]	33.11	-	49.53	16.42	49.6%

[1] Total FY 2018 Actual funding for NRT is $53.85 million with $20.74 million contributed from the R&RA account. In FY 2020, all funding for NRT resides in the EHR account.

About DGE

DGE provides leadership 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.

FY 2020 priorities for DGE include:

- Maintain its SFS 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.
- Continue the goal of GRFP to help build the U.S. STEM human capital necessary to ensure the Nation's leadership in advancing innovations in science and engineering.
- Invest in the NRT program, including the Innovations in Graduate Education (IGE) track.

For more information on GRFP and NRT, see the Major Investments in STEM Graduate Education narrative within the NSF-Wide Investments chapter.

FY 2020 Summary

Learning and Learning Environments

- The PPE requested funding level is zero. In FY 2020, EHR will continue to support monitoring and data collection efforts through its existing programs' budgets. The Promoting Research and Innovation in Methodologies for Evaluation (PRIME) solicitation will remain on hiatus in FY 2020.

STEM Professional Workforce

- SFS is funded at $55.09 million. This funding will improve the capacity of institutions to provide the latest curricular and assessment approaches and experiences available to ensure that students are well prepared with cybersecurity skills and knowledge. This funding will also allow institutions to conduct research to build understanding of the most effective preparation for a variety of cybersecurity professions. Through SFS, EHR will invest in the cybersecurity education and workforce development component of NSF's SaTC investment area.

- ECR: STEM Professional Workforce Preparation is funded at a total of $10.99 million. This investment will expand the knowledge base to improve STEM professional workforce development at all educational levels through development of models, research, and evaluation.
- GRFP is provided $128.45 million. EHR's resources together with matching funds in the IA budget provide a total FY 2020 funding level of $256.90 million to support 1,600 new fellowships with a cost of education allowance of $12,000 and a stipend of $34,000 per fellow.
- NRT is provided $49.53 million with all FY 2020 funding resources residing in EHR. This funding will support graduate training and research projects that align with NSF-wide priority areas. Of the NRT budget, $8.0 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 of science, and will seek bold new STEM graduate education pilots and models to transform current practices in graduate education. Through the program's traineeship track, NRT also will support FY 2020 projects related to three NSF Big Ideas (HDR, FW-HTF and NNA).

H-B NONIMMIGRANT PETITIONER FEES **$120,000,000**

In FY 2019, H-1B Nonimmigrant Petitioner Fees are projected to be $120.0 million.

H-1B Nonimmigrant Petitioner Fees Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request	FY 2020 Request Change Over FY 2019 Estimate Amount	Percent
H-1B Nonimmigrant Petitioner Fees Funding	$192.26	$120.00	$120.00	-	-

Beginning in FY 1999, Title IV of the American Competitiveness and Workforce Improvement Act (ACWIA) 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).

The FY 2020 Request includes a legislative proposal to double the ACWIA fee for the H-1B visa program (to $3,000 per worker for large employers and $1,500 for small employers) to prepare American workers for jobs that are currently being filled by foreign workers, especially in STEM fields. Under the proposal, NSF's allocation for the ITEST program (10 percent) would remain the same, while its allocation for S-STEM would decrease from 30 percent to 15 percent, a level that would maintain absolute funding levels under current estimates.

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM).

The S-STEM program began in 1999 under P.L. 105-277. Originally, 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 more than 7,000 proposals from all types of colleges and universities and has made 2,017 awards. In addition to scholarships, S-STEM awards also provide funding for student support activities featuring close involvement of faculty, student mentoring, academic support, curriculum development, and recognition of student accomplishments. Such activities are important in recruiting and retaining students in high-technology fields through graduation and into employment. In FY 2020, in addition to the long-standing scholarship support, all S-STEM projects will continue to conduct research on interventions that affect associate or baccalaureate STEM degree attainment by 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, this research is important to understand this success so that effective practices can be used at scale. Approximately 90 awards are anticipated in FY 2020, with a continued emphasis on increasing involvement of community colleges, especially Hispanic-serving institutions. S-STEM activities in FY 2020 will leverage efforts in IUSE: EHR, LSAMP, and the IUSE: HSI Program to enhance persistence of students. S-STEM will continue to be a partner in the NSF INCLUDES initiative. S-STEM programming and research also will align with NRT, with the goal of understanding and enhancing effective learning environments and pathways for students on the continuum from two-year to four-year to master's and 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 3,751 grant proposals and made 488 awards (including co-funded projects) that allow K-12 students and teachers to work closely with scientists, engineers, and other STEM professionals on extended research projects that promote awareness of STEM careers and interest in pursuing education pathways to those careers. Funded projects draw on a wide mix of local resources, including universities, industry, museums, science and technology centers, and school districts to identify the characteristics that attract a wide and diverse range of young people to STEM careers, especially those students historically underrepresented in those careers. In FY 2020, ITEST will be a partner in the NSF INCLUDES initiative and will make approximately 25-30 awards.

H-1B Financial Activities from FY 2009 - FY 2018

(Dollars in Millions)

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Receipts	**$88.66**	**$91.22**	**$106.11**	**$128.99**	**$120.94**	**$132.49**	**$143.00**	**$138.80**	**$141.07**	**$155.99**
Unobligated Balance start of year	**$50.83**	**$52.62**	**$50.15**	**$60.93**	**$99.31**	**$108.31**	**$111.39**	**$116.02**	**$74.63**	**$96.86**
Appropriation Previously unavailable (Sequestered)						**$5.10**	**$9.54**	**$7.30**	**$6.80**	**$9.73**
Appropriation Currently unavailable (Sequestered)						**-$9.54**	**-$7.30**	**-$6.80**	**-$9.73**	**-$10.30**
Obligations incurred:										
Scholarships in Science, Technology, Engineering, and Mathematics	61.22	75.96	77.67	72.57	83.98	92.18	109.34	140.54	84.38	156.40
Private-Public Partnership in K-12	27.86	20.85	18.62	21.59	31.51	37.23	29.83	44.35	35.11	35.86
Total Obligations	**$89.08**	**$96.81**	**$96.29**	**$94.16**	**$115.49**	**$129.41**	**$139.17**	**$184.89**	**$119.49**	**$192.26**
Unallocated Recoveries		2.20	3.12	0.96	3.55	-	4.95	1.60	3.58	4.66
Unobligated Balance end of year	**$50.41**	**$49.24**	**$63.09**	**$96.72**	**$108.31**	**$111.39**	**$122.41**	**$72.03**	**$96.86**	**$64.68**

[1] P.L. 108-447 directs that 10 percent of the H-1B Petitioner funds go toward K-12 activities involving private-public partnerships in a range of areas such as materials development, student externships, math and science teacher professional development, etc.

Explanation of Carryover

Within the H-1B no-year account, $64.68 million was carried over into FY 2019.

Innovation Technology Experiences for Students (ITEST)
- Amount: $22.08 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 2019 Quarter 4

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)
- Amount: $26.98 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 2018 Quarter 4.

The remaining $15.62 million consists of unallotted recoveries.

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION (MREFC) **$223,230,000**
-$72,510,000 / -24.5%

Major Research Equipment and Facilities Construction Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Enacted	FY 2020 Request	Change over FY 2019 Enacted Amount	Percent
MREFC	$186.30	$295.74	$223.23	-$72.51	-24.5%

MREFC Overview

The Major Research Equipment and Facilities Construction account supports the acquisition, construction, and commissioning of major and mid-scale 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 R&RA account.

MREFC Account Funding, by Project
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Enacted	FY 2020 Request	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
AIMS	-	$103.70	$97.89	$90.00	$90.00	$28.81	-	-
DKIST[1]	18.24	16.13	-	-	-	-	-	-
HL-LHC Upgrade	-	-	33.00	33.00	33.00	33.00	18.00	-
LSST[1]	66.70	48.82	46.34	40.75	5.36	-	-	-
Mid-scale Research Infrastructure[2]	-	-	45.00	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*
NEON[3]	12.79	-	-	-	-	-	-	-
RCRV[1]	88.00	127.09	-	-	-	-	-	-
Dedicated Construction Oversight[4]	0.56	*[1.00]*	1.00	1.00	1.00	1.00	1.00	1.00
Total	**$186.30**	**$295.74**	**$223.23**	**$164.75**	**$129.36**	**$62.81**	**$19.00**	**$1.00**

[1] Of the funding appropriated to DKIST, LSST, and RCRV, $3.46 million, $4.74 million, and $17.0 million, respectively, is excluded in the amounts above. This is being held as part of NSF's enhanced oversight of budget contingency

[2] Mid-scale Research Infrastructure funding in the FY 2019 Request is reflected in the R&RA account within Integrative Activities. In the FY 2020 Request, $30.0 million remains in Integrative Activities to support mid-scale infrastructure in the $6 million to $20 million range. Outyear funding levels for Mid-scale will be shown in future budget requests.

[3] No new funds were appropriated for NEON in FY 2018. The FY 2018 Actual obligations reflect spending of prior year carryover in FY 2018, and $1.42 million was carried over for future obligation.

[4] In FY 2019, support for Dedicated Construction Oversight activities will be funded from prior year recoveries.

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 major research infrastructure projects included in this budget request meet these criteria based on NSF and National Science Board review and approval. The mid-scale projects funded through this budget line are evaluated separately as described in the section below.

In FY 2020, NSF requests $223.23 million for mid-scale research infrastructure and to continue construction on four ongoing major research infrastructure projects: the Antarctic Infrastructure

Modernization for Science (AIMS), the High Luminosity-Large Hadron Collider (HL-LHC), the Large Synoptic Survey Telescope (LSST), and the Regional Class Research Vessels (RCRV). For more information on each major research infrastructure project see the individual narratives later in this chapter.

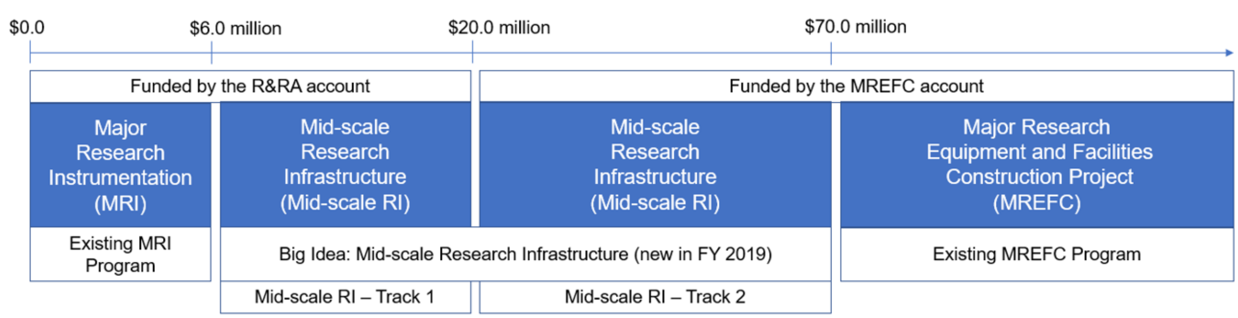
Major Research Infrastructure (Major Facilities)

Since FY 2009, major research infrastructure 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 such that approved budgets are sufficient to accomplish the scientific objectives. The current policy as published in NSF’s Large Facilities Manual (to be replaced by the Major Facilities Guide, or MFG, by the start of FY 2020) 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 transferred to MREFC, with Congressional approval..

Mid-scale Research Infrastructure

As part of the American Innovation and Competitiveness Act (AICA) of 2017, Congress required the agency to develop a strategy for supporting research infrastructure with a total project cost above the upper limit for the Major Research Instrumentation (MRI) program, $5.71 million, and below the lower threshold for the MREFC account, $70 million. NSF has evaluated community demand through the issuance of a Request for Information (NSF 18-013) that resulted in the submission of approximately $10 billion in ideas for projects in the NSF cost range of $20 - $100 million. After evaluating that community input, existing mechanisms, and implementation options, NSF is proposing a new dedicated line within the MREFC account for research infrastructure projects in the $20 - $70 million range. Prior to this, such large mid-scale projects could only be minimally supported by the individual directorates due to constraints on R&RA funding. This dedicated funding line implements a high-priority, agency-wide mechanism that includes up-grades to major facilities as well as stand-alone projects, such that all research infrastructure investments above $20 million will be managed as a single portfolio. Individual projects will be selected from submissions to a dedicated program solicitation developed in FY 2019, using NSF’s merit review process. Once selected, funding will be allocated from the MREFC account to the responsible directorate for award. The lower part of the mid-scale gap, between $6 million and $20 million in Total Project Cost, will be addressed by the individual directorates and by a new program drawing its heritage from the NSF-wide MRI program.

NSF Portfolio of Central Instrumentation and Infrastructure Implementation Programs



This graphic shows NSF’s central instrumentation and infrastructure programs. Information presented in this chapter focuses on the MREFC account. Information on Mid-scale Research Infrastructure programs, Mid-scale track 1 and track 2 , as part of the Mid-scale Big Idea, can be found in the Mid-scale narrative in the NSF-wide priorities chapter. Information on the MRI program can be found in the IA narrative in the R&RA chapter.

Dedicated Construction Oversight
All projects funded through the MREFC account undergo periodic cost, schedule, and risk reviews as required by the MFG 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.

NSF has greatly strengthened its oversight of major facility projects in recent years, with a number of those enhancements now codified in AICA. One significant enhancement is holding a portion of budget contingency (up to 100 percent) and only allocating contingency funds for obligation to the project based on demonstrated need. This oversight mechanism will generally result in some MREFC carryover each year. However, future obligation of this carryover 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 NSF's 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. In FY 2017 and FY 2018, these activities were supported with funds recovered from projects completed in previous years. In FY 2019 and FY 2020, funding is requested for these activities in the MREFC account.

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, ~~$94,650,000,~~ $223,230,000, to remain available until expended.

Major Research Equipment and Facilities Construction
FY 2020 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 2018 Appropriation	$182.80	$31.36	-$28.43	$0.57	-	$186.30
FY 2019 Annualized CR	182.80	28.43				211.23
FY 2019 Enacted	295.74					295.74
FY 2020 Request	223.23					223.23
$ Change from FY 2019 Enacted						-$72.51
% Change from FY 2019 Enacted						-24.5%

Explanation of Carryover

Within the Major Research Equipment and Facilities Construction (MREFC) account, $28.43 million was carried over into FY 2019.

Regional Class Research Vessels
- Amount: $17.0 million
- Reason: FY 2017 appropriation exceeded project requirements and unobligated FY 2018 budget

contingency.

- Obligation: Anticipated FY 2019 Quarter 3; and combined with FY 2019 funding to exercise option on the third hull.

Large Synoptic Survey Telescope

- Amount: $4.74 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Daniel K. Inouye Solar Telescope

- Amount: $3.46 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 4

National Ecological Observatory Network

- Amount: $1.42 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Dedicated Construction Oversight

- Amount: $1.24 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 4

The remaining $570,000 consists of funds from selected projects that were not ready for obligation in FY 2018.

ANTARCTIC INFRASTRUCTURE MODERNIZATION FOR SCIENCE (AIMS) $97,890,000

The Antarctic Infrastructure Modernization for Science construction project will be initiated in FY 2019 with an investment of $103.70 million. The FY 2020 Budget Request amount is $97.89 million, the second year in a multi-year funding profile. See Baseline History below for a discussion of the Total Project Cost.

Requested Funding Requirements
for the Antarctic Infrastructure Modernization for Science Project

(Dollars in Millions)

FY 2019 Estimate	FY 2020 Request	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	Total Project Cost
$103.70	$97.89	$90.00	$90.00	$28.81	$410.40

In the FY 2019 Request, funding for AIMS was presented in the Office of Polar Programs within the R&RA account. However, in FY 2019 P.L. 116-6 appropriated $103.70 within the MREFC account for AIMS. As such, the FY 2020 Budget Request presents funding for AIMS in the MREFC account.

The AIMS project will replace major facilities at McMurdo Station, Antarctica, one of three permanent stations that comprise the U.S. presence in Antarctica, to meet anticipated science support requirements for the next 35 to 50 years. The project will help ensure enduring U.S. leadership and influence in this strategic region. It will also support critical scientific research and capabilities such as nuclear test detection, earthquake monitoring, and real-time weather data collection for global forecasting.

McMurdo Station’s main purpose is to support both near- and deep-field science in Antarctica including activities at Amundsen-Scott South Pole Station. AIMS will enable faster, more streamlined logistical and science support by co-locating or consolidating field science support, warehousing, skilled trades work, and personnel and administrative support into more operational and energy efficient facilities. AIMS will also provide lodging replacement facilities, a vehicle equipment operations center, an emergency operations center, and necessary upgraded utilities to support these facilities.

FY 2019 funds were used for initial procurements of material that will be transported to McMurdo Station in early FY 2020, in preparation for the beginning of major AIMS construction. Site preparation work also is beginning in FY 2019. FY 2020 funds will be used to continue site preparation work for the backbone utilities and the initial buildings, continue to procure the first phases of construction materials and associated equipment, and begin construction. The AIMS Project is currently anticipated to take up to 10 years to complete.

Baseline History

In 2011, the Office of Science and Technology Policy and NSF convened a Blue Ribbon Panel (BRP) to evaluate the U.S. Antarctic Program (USAP) logistical enterprise. The BRP was asked to conduct a review of NSF facilities and operations supporting science in Antarctica and to ensure that it can support the scientific opportunities articulated by an earlier 2011 National Research Council report entitled *Future Science Opportunities in Antarctica and the Southern Ocean*. The BRP report made numerous recommendations regarding maintaining and enhancing the U.S.’s world-class science program in Antarctica.

NSF responded to the BRP report by immediately addressing issues of safety, implementing operational efficiencies which resulted in immediate return on investment, and developing long-term plans for each of the three year-round U.S. stations: Palmer, Amundsen-Scott South Pole, and McMurdo. The AIMS project is a pivotal component of the McMurdo Station Master Plan with a specific focus on the primary core functions of this critical logistics hub.

The AIMS project seeks to enhance operational support for science by improving operations efficiency, containing operating costs, and enhancing safety. The following major scope elements are targeted to achieve these goals:

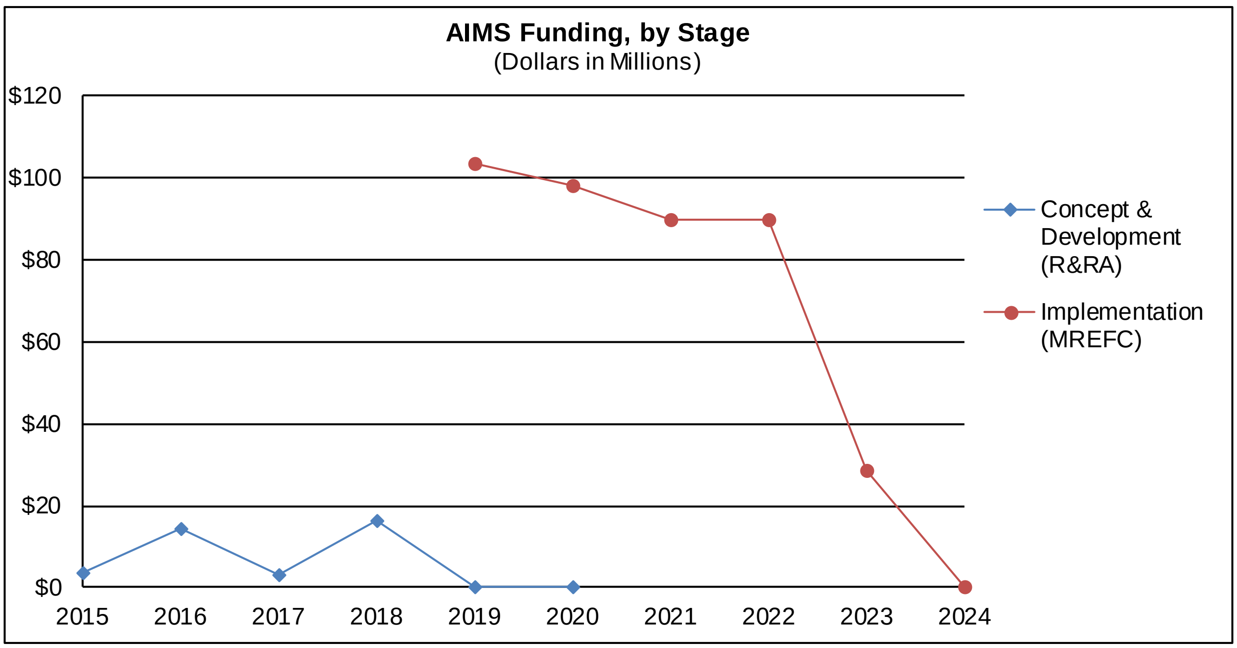
- Construction of a Centralized Services Building that replaces and modernizes multiple existing facilities on station including centralized warehousing.
- Construction of an Emergency Operations Facility to replace the existing Fire Station, Medical Facilities, and Fitness and Skills Development Facilities.
- Construction of a consolidated Field Science Support Facility.
- Construction of an Industrial Trades Shop to consolidate existing facilities across the station.
- Construction of a Vehicle Equipment Operations Facility (VEOC) that facilitates maintenance and repair of both heavy and light equipment ranging from traverse tractors, cranes, loaders, and earth moving equipment to trucks, vans, snowmobiles, field generators, etc.
- Construction of one new lodging facility to ensure adequate bed space to support near term needs, including population surges from an influx of construction workers. Importantly, this facility is comprised primarily of single-occupancy rooms needed to promote safety and health. Shared rooms exacerbate sleep disturbance that can arise from widely varying work and travel schedules for the station workforce as well as scientists and promote the spread of contagious conditions such as colds and flu.
- Upgrade of utilities distribution networks for fire protection water, domestic water, heating, power, communications, and sanitary sewer.

The Preliminary Design Review (PDR) held in December 2016 examined the baseline cost, scope, and schedule utilizing information and conditions available at that time. After an analysis of all information, the result of PDR, and an independent cost assessment, NSF estimated a Total Project Cost (TPC) of $355.0 million for AIMS. The National Science Board authorized NSF to request funds for AIMS, and the estimated TPC of $355.0 million was reflected in the FY 2019 Budget Request. During the two-year interval before the Final Design Review, significant unforeseen cost increases occurred that yielded initial estimates for a TPC as high as $450 million. These potential increases were externally driven and largely due to two causes: (1) significantly increased civil construction costs, related to robust construction opportunities in the continental U.S. that are lower risk compared to AIMS, including responses to several major hurricane and flood events; and (2) substantial global increases in commodity prices. The prime Antarctic Support Contractor was directed by NSF to undertake a reassessment and value engineering process that evaluated several options, including a de-scoped project that would retain the $355.0 million estimate. Holding to the previous cost estimate would severely impact the ability to support science from McMurdo Station, and compromise the health, safety, and efficiency that were integral parts of the AIMS design. However, significant savings were found by re-designing structures and eliminating features that were less critical to overall operational support, while retaining the major scope elements and required capabilities described above. These efforts resulted in a final TPC of $410.40 million. An Independent Cost Estimate was conducted by the Army Corps of Engineers in accordance with NSF procedures. The TPC of $410.40 million was authorized by the National Science Board in February 2019.

Total Funding Requirements for AIMS
(Dollars in Millions)

	Prior Years	FY 2018 Actual	FY 2019 Estimat	FY 2020 Request	ESTIMATES FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design	$21.17	$16.14	$0.37	-	-	-	-	-	
Subtotal, R&RA	$21.17	$16.14	$0.37	-	-	-	-	-	-
MREFC:									
Implementation[1]	-	-	103.70	97.89	90.00	90.00	28.81	-	-
Subtotal, MREFC	-	-	$103.70	$97.89	$90.00	$90.00	$28.81	-	-
TOTAL REQUIREMENTS	**$21.17**	**$16.14**	**$104.07**	**$97.89**	**$90.00**	**$90.00**	**$28.81**	**-**	**-**

[1] FY 2019 Request funding was presented in the Office of Polar Programs within the R&RA account. However, in FY 2019 P.L. 116-6 appropriated $103.70 million within the MREFC account for AIMS. As such, the FY 2020 Budget Request presents funding for AIMS in the MREFC account.



Note: Outyear (FY 2020 through FY 2024) Implementation funding reflects current estimates.

Management and Oversight

AIMS will be accomplished under the Federal Acquisition Regulations (FAR) via an existing contract to Leidos Innovations Corporation as the current Antarctic Support Contractor. The Office of Polar Programs will work in collaboration with the Division of Acquisition and Cooperative Support (DACS) to use existing contract mechanisms (e.g., monthly program reviews, earned value reporting, award fee evaluation) to ensure rigorous management and oversight of this work. Appropriate NSF major facility oversight requirements will apply, including engagement of the Large Facilities Office (LFO) and use of Independent Cost Estimates, with due consideration of award through a FAR-based contract.

Reviews

- Conceptual Design Review (CDR): CDR was conducted March 31-April 2, 2015. The NSF program staff concurred with the external 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 December 2016. The external 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 was ready to proceed to the Final Design Phase. Following NSF deliberations, the National Science Board passed a resolution (NSB-2017-20) authorizing NSF to include AIMS in a future budget request.
- Final Design Review (FDR): FDR was conducted October 2018. The external panel found that the project execution plan was well-developed for the FDR and recommended that the project proceed to the construction stage. They also recommended that NSF attempt to retain all the major science-suppport capabilities in the original scope, in spite of the cost increase, in order to realize the long-term benefits needed by the USAP. An Independent Cost Estimate also was carried out as part of the FDR process.

Project Status

Leidos continues to advance the designs of AIMS and is in the process of preparing a final proposal for a contract modification anticipated in March 2019. On February 12, 2019 NSF received authorization from the National Science Board to proceed with construction.

Cost and Schedule

FY 2020 funds will be used to continue site preparation work for the backbone utilities and the initial buildings, continue to procure the first phases of construction materials, and begin construction. Construction will be phased to allow for minimal impact on science support during construction, as well as ensure continuity of operations in the event that subsequent funding is disrupted. The evolution of the Total Project Cost was discussed above. Although the actual execution of the entire AIMS Project is expected to take 8-10 years, the proposed appropriation profile is shorter in order to reduce risks (e.g., due to market conditions) and to facilitate the lengthy supply chain (see Risks section below).

Risks

The primary risks at this stage of the project (i.e., prior to contract award) are associated with the uncertainty in market conditions at the time of subsequent contract modifications, affecting labor and materials. During construction, a key risk is the lengthy supply chain required to get the necessary labor and materials to Antarctica when needed. NSF and Leidos have implemented a rigorous risk management approach which includes the identification of risks and mitigating actions.

Future Operations Costs

Implementing AIMS will provide a material reduction in the annual cost to maintain and operate McMurdo station including an estimated $1.80 million in fuel and $4.20 million in labor and other direct costs in comparison with FY 2018 operating costs. By consolidating the station footprint and using modern energy efficient designs, AIMS will save an estimated 494,000 gallons per year of fuel. Consolidated warehousing and co-located workcenters will permanently reduce the support labor requirement by 80 workers. The new layout will enable improved quality of support and increase the throughput of field science projects.

DANIEL K. INOUYE SOLAR TELESCOPE (DKIST) $0

No funding is requested in FY 2020 for construction of NSF's Daniel K. Inouye Solar Telescope. FY 2019 represented the final year in an 11-year funding profile within an NSB approved not-to-exceed total project cost of $344.13 million. Completion of construction atop Haleakalā on Maui, Hawai'i is planned for no later than June 2020. This narrative provides an update on the project's status.

Appropriated and Requested MREFC Funds for the Daniel K. Inouye Solar Telescope
(Dollars in Millions)

	Prior Years	FY 2015 Actual	FY 2016 Actual	FY 2017 Actual	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request[1]	Total Project Cost
MREFC Approp.	$96.88	$25.12	$20.00	$20.00	$20.00	$16.13	-	$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	146.00
Total	**$242.88**	**$25.12**	**$20.00**	**$20.00**	**$20.00**	**$16.13**	**-**	**$344.13**

[1] FY 2019 was the final year for MREFC funding for DKIST construction. The Project is currently on track to complete construction in 2020 within the Total Project Cost cap.

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 impact the terrestrial climate. The relevance of DKIST's science drivers was reaffirmed by the National Academies of Sciences, Engineering, and Medicine 2010 Astronomy and Astrophysics decadal survey: *New Worlds, New Horizons in Astronomy and Astrophysics*[1] as well as the 2012 Solar and Space Physics decadal survey: *Solar and Space Physics: 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*[3] both of which were released by the National Science and Technology Council in October 2015. An update to the National Space Weather Strategy and Action Plan has been developed through the Space Weather Operations, Research, and Mitigation Working Group of the National Science and Technology Council and was informed by community input received through the Federal Register (83 FR 17526). This update, currently undergoing committee review within the Office of Science and Technology Policy, reaffirms a fundamental research objective that includes "Understanding the underlying physical processes of the Sun that drive space weather events…"

Baseline History

Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year development and design program for DKIST and its initial complement of instruments through the Division of Astronomical Sciences (AST) in MPS and through the Division of Atmospheric and Geospace Sciences in 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

[1] www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics
[2] www.nap.edu/catalog/13060/solar-and-space-physics-a-science-for-a-technological-society
[3] www.hsdl.org/?view&did=789864

2009, which determined that the project was fully prepared to begin construction. 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.

The DKIST telescope enclosure and Support and Operations building at the site on Haleakalā, Maui, HI. *Credit: David Boboltz, NSF.*

The environmental compliance requirements were completed on November 20, 2009, and the NSF Director signed the Record of Decision authorizing construction in December 2009. The Hawai'i Board on Land and Natural Resources (BLNR) approved the project's application for a Conservation District Use Permit (CDUP) in December 2010. 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 Haleakalā followed shortly thereafter. Site preparation and excavation began in November 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 recommended increasing the total project cost by approximately $46.20 million. The NSB subsequently considered and approved a revised total project cost of $344.13 million at its August 2013 meeting.

Total Funding Requirements for DKIST

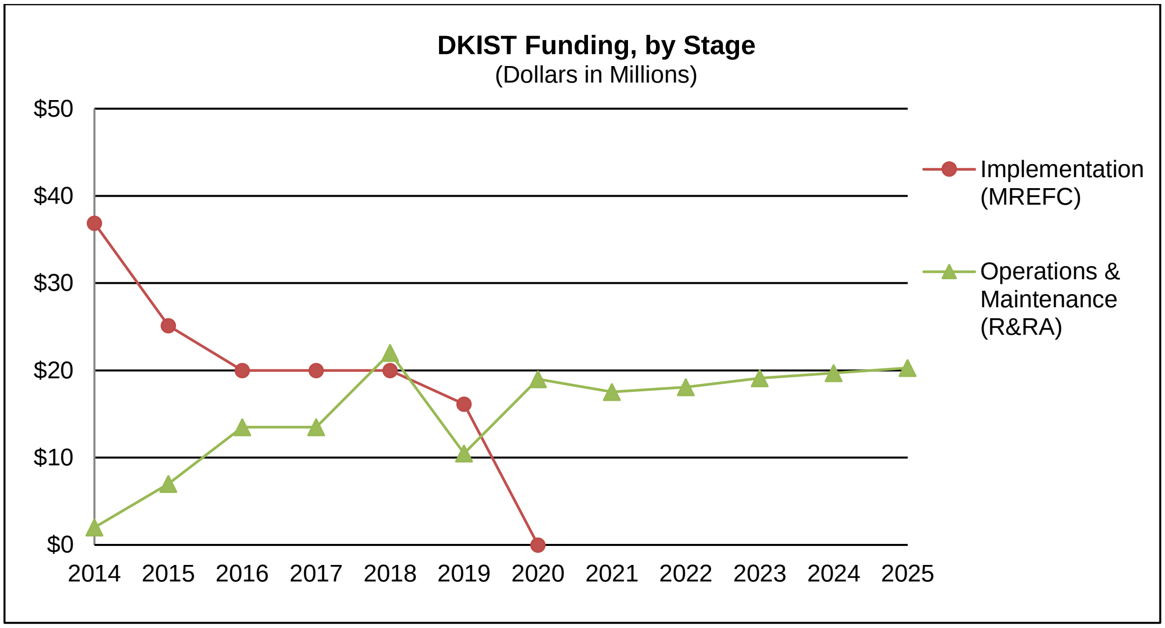
(Dollars in Millions)

	Prior Years	FY 2018 Actual[1]	FY 2019 Estimate	FY 2020 Request	ESTIMATES FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design	$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance[2]		24.00	10.50	19.01	17.54	18.08	19.13	19.71	20.30
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	$23.51	$24.00	$10.50	$19.01	$17.54	$18.08	$19.13	$19.71	$20.30
MREFC:									
Implementation[3]	162.00	20.00	16.13	-	-	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	$308.00	$20.00	$16.13	-	-	-	-	-	-
TOTAL REQUIREMENTS	**$331.51**	**$44.00**	**$26.63**	**$19.01**	**$17.54**	**$18.08**	**$19.13**	**$19.71**	**$20.30**

[1] FY 2018 obligations included $8.0 million to fund part of the FY 2019 costs.

[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.

[3] Includes $3.46 million carried forward into FY 2019.



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 partnership activities include:

- The U.S. Air Force (USAF) replaced the aluminizing chamber at their Advanced Electro-Optical System telescope on Maui and sized it to accommodate the DKIST primary mirror. An Interagency Agreement for use of the Mirror Coating Facility (MCF) was signed by NSF and the U.S. Air Force in FY 2017. This eliminates the need to build a dedicated aluminizing chamber for DKIST.
- Kiepenheuer-Institut für Sonnenphysik (KIS; Freiburg, Germany) is constructing a narrow-band instrument named the Visible Tunable Filter (VTF) as an in-kind contribution.
- Queens University 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: NSF oversight 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 the General Counsel (OGC), and the Office of Legislative and Public Affairs. Within BFA, the Large Facilities Office (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, which meets on a quarterly basis to discuss outstanding project issues.
- External Structure: NSO conducts the construction project. 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 managing organization, the Association of Universities for Research in Astronomy, Inc. (AURA). The DKIST CSA for construction expires June 30, 2020. In 2015, the NSO CA and O&M CSA were renewed 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 DKIST. The project manager has experience in large telescope development, having served as lead telescope engineer for the Gemini Telescopes project. Several councils and working groups give 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.
- Independent Risk Assessment (IRA): LFO engaged a contractor to perform an independent assessment of the project's remaining risks as DKIST entered the critical integration, testing and commissioning (IT&C) stage of construction. The IRA consisted of a document desk review followed by an in-person meeting in September 2017. The final report was received by NSF in December 2017. The final report transmittal memo from the contractor states: "We are pleased to report that the DKIST project has a mature risk management program that is well-positioned entering the Integration, Testing, and Commissioning (IT&C) phase. We found no critical areas that require corrective action."
- Government Accountability Office (GAO) Study: Based on congressional interest (Senate Report 114-289), the GAO assessed "NSF Major Projects", which included the DKIST construction project. The GAO final report was issued in June 2018. The GAO characterized the DKIST Project as one of two NSF projects that have experienced both cost and schedule increases. As described above, the cost and schedule increases were due to 30 months of unavoidable permitting delays, which resulted in the 2013 re-baseline of the project.
- Programmatic Review: A comprehensive external programmatic review of the DKIST MREFC construction project is scheduled for April 2019 in Boulder, CO. In addition to an assessment of the project's status against the Project Execution Plan, the review will focus on project close-out and criteria for acceptance.
- Earned Value Management (EVM) System Surveillance: In conjunction with the programmatic review described above, a one-day surveillance of the project's EVM system will be conducted in April 2019. This surveillance will provide an updated assessment of the project's previously validated EVM system.

Project Status

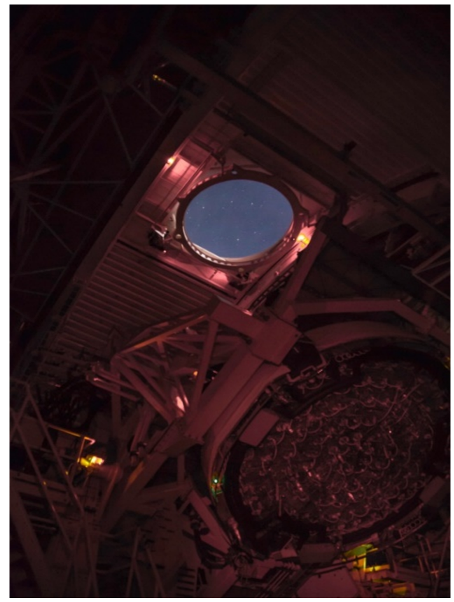
The DKIST project continues to make progress on construction at the summit of Haleakalā on Maui, HI, while remaining in compliance with all local, state, and federal environmental and cultural requirements. The project continues to consult with various stakeholders on a regular basis including the Hawaiʻi Department of Land and Natural Resources, the Hawaiʻi Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the Federal Aviation Administration, the National Park Service, and Native Hawaiʻian cultural practitioners.

<u>Construction highlights</u>:

- A Level 1 milestone was achieved in FY 2018 with the completion of the Telescope Mount Assembly (TMA).
- In FY 2018 the primary (M1) mirror and the M1 Cell Assembly were successfully transported to Maui. The M1 commissioning blank and the M1 were both successfully coated at the USAF MCF. The M1 Cell Assembly successfully underwent site acceptance testing. The M1 commissioning blank was installed in the TMA to test the full range of motion under the mirror load. The M1 was installed in the Cell Assembly and the entire package installed on the TMA for initial alignment.
- In early FY 2019, DKIST achieved its first images of star light and completed its first pointing model using a temporary Nighttime Acquisition Telescope mounted at the telescope prime focus.
- In FY 2019, the project will continue to implement the critical IT&C phase of construction.
- Fabrication of the first of the DKIST instruments, the visible broadband imager (VBI), will be completed and the VBI delivered in FY 2019.

- In FY 2019 the project is expected to achieve another Level 1 milestone, i.e., first-light on the sun with the VBI instrument.

In FY 2020 the project will continue to work through the final stages of IT&C and the integration of all first-light instruments. By Q4 of FY 2020, it is expected that DKIST will have achieved its final Level 1 milestone—Start of Operations.



A view looking upward through the telescope enclosure entrance aperture during the first evening of on-sky tracking and pointing tests of DKIST. *Credit: Shawn Granen, DKIST/NSO.*

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 2020 at an 80 percent confidence level for successful completion. The project is currently on track for a FY 2020 end date.[4]

Risks

Project management control, interface control, and change controls are in place. The project also maintains a risk register that is reviewed and updated monthly.

<u>Technical</u>: Most of the remaining technical risks are relatively low because of the long development and design phase. The CSA between NSF and AURA identifies four facility-class instruments to be delivered by the DKIST project at the end of the MREFC construction phase. The Project is on track to deliver those four instruments. The VTF is a fifth instrument and is an in-kind contribution from the German KIS being designed and developed through a Memorandum of Understanding between AURA and KIS; therefore, the risks for this instrument remain with the German institute. KIS is currently on track to deliver the VTF instrument to DKIST prior to the start of operations.

<u>Environmental and Cultural Compliance</u>: AST, NSF's OGC, 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 Hawai`ian working group continue. Following the November 2012 issuance of the CDUP as mentioned in the Baseline History section above, several challenges to both the CDUP and the University of Hawai`i's Haleakalā Observatory (HO) management plan made their way through the State court system. In October 2016, the Hawai`i Supreme Court ruled against the appellant in both cases, upholding both the project's CDUP and the HO management plan. Remaining environmental and cultural compliance risks are low since the project continues to be in compliance with all requirements as defined in the Biological Opinion (BO),[5] the Habitat Conservation Plan (HCP),[6] and the Programmatic Agreement.

[4] At the time of writing in February 2019, commercial power to Haleakala has been off-line for several weeks, possibly to extend up to two months, due to severe storm damage in Maui, Hawai'i. This could cause a minor delay in project completion.

[5] At the time of this writing, February 2019, compliance obligations contained within the U.S. Fish and Wildlife Service's (USFWS') BO have been met and closed out via a letter to NSF from the USFWS.

[6] At the time of this writing, February 2019, NSF is scheduled to appear before the Endangered Species Recovery Committee in March 2019 seeking a recommendation to close out compliance obligations as listed in the State of Hawai'i Division of Forestry and Wildlife HCP.

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 conducts annual external safety reviews. In addition, safety updates are provided to NSF by the project on an monthly basis and DKIST project safety is one of the topics covered in the annual external program reviews.

Operations Costs

DKIST operations are funded through R&RA. In FY 2020, the projected budget of $19.01 million includes $17.01 million for DKIST operations and $2.0 million for cultural mitigation activities as agreed to during the compliance process. This will be the final year of the 10-year award for cultural mitigation activities.

HIGH LUMINOSITY-LARGE HADRON COLLIDER UPGRADE (HL-LHC) $33,000,000

NSF requests $33.0 million in FY 2020 to begin upgrading components of the A Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) detectors to operate at the High Luminosity-Large Hadron Collider (HL-LHC). This is the first year of support for a five-year construction project with a preliminary total project cost of $150.0 million

Appropriated and Requested MREFC Funds for the High Luminosity-Large Hadron Collider (HL-LHC) Upgrade
(Dollars in Millions)

Prior Years	FY 2020 Request	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	Preliminary Project Cost
-	$33.00	$33.00	$33.00	$33.00	$18.00	$150.00

The Large Hadron Collider (LHC) is the world's largest and highest energy particle accelerator. Located near Geneva, Switzerland, and operated by the European Organization for Nuclear Research (CERN), the LHC can accelerate and collide counter-propagating bunches of protons at a total energy of 14 tera-electron volts (TeV). Physicists study the debris from these collisions to learn about the elementary particles and fundamental forces that shape the universe. ATLAS and CMS are two general purpose detectors used by researchers to observe these collisions and analyze their characteristics.

Baseline History

Since 2011, U.S. funding for ATLAS and CMS operations and maintenance (O&M) funding has included investments in advanced research and development (R&D) for investigations into detector modifications that will enable them to function at much higher collision rates following an upgrade to the LHC to increase its luminosity. Each detector group, comprised of researchers from all participating countries, developed a scoping document[1] that described its scientific goals and the technical path forward for operation in the challenging HL-LHC environment.

In 2014, the Particle Physics Project Prioritization Panel (P5) , a subcommittee of the High Energy Physcis Advisory Panel that advises NSF and the U.S. Department of Energy (DOE), recommended U.S. participation in the detector upgrades. In fall 2014, MPS charged a subcommittee of the MPS Advisory Committee (MPS AC) to advise on an appropriate response. The subcommittee, with MPS AC endorsement, recommended NSF provide construction funding at the MREFC level to enable meaningful participation by NSF-supported scientists in the HL-LHC research program.

In November 2015, the NSF Director approved entry of the HL-LHC upgrade to the ATLAS and CMS detectors into the Conceptual Design phase. The principal objectives of this activity were to define a quantitative statement of science requirements, develop a flow-down of the science requirements to a set of technical requirements, define the major technical components, and provide NSF with a top-down estimate of the associated cost, schedule, and risk. Conceptual Design Reviews (CDR) in March-April 2016 established the major functional elements of each detector designated for NSF support and determined that these elements would enable the principal science objectives within the $150.0 million funding envelope defined by NSF in consultation with the MPS AC.

In August 2016, the NSF Director approved entry into the Preliminary Design phase. The principal goals of this phase were to develop a detailed technical description of the scope to be fabricated, the risk-adjusted total project cost for each detector based on bottom-up cost estimates, the corresponding resource-loaded

[1] Atlas: https://cds.cern.ch/record/1502664?ln=en; CMS: http://cds.cern.ch/record/2020886

schedules, year-by-year budget profiles for construction, and plans for managing risk. NSF directed that the total project cost should not exceed $150.0 million, or $75.0 million for each detector. NSF conducted Preliminary Design Reviews (PDR) of CMS and ATLAS, in December 2017 and January 2018 respectively, which established that ATLAS and CMS met the PDR requirements. The review panels expressed confidence that the MREFC scope for each detector upgrade could be accomplished within its individual preliminary $75.0 million MREFC budget cap. NSF subsequently carried out a comprehensive cost analysis that substantiated the basis of estimate for the requested construction budgets.

In July 2018, the NSB authorized the NSF Director to include construction of the High Luminosity upgrades to the ATLAS and CMS detectors in a future Budget Request.

Science Plan

Initial operation of the LHC, and the ATLAS and CMS detectors, enabled the discovery of the Higgs boson in 2012, leading to the 2013 Nobel Prize in Physics. The Higgs mechanism explains how fundamental particles acquire mass. This represents the last major piece in the Standard Model of Particle Physics, which describes all fundamental particles and their interactions. Despite this historic accomplishment, the ATLAS and CMS experiments have only scratched the surface of the ultimate physics potential of the LHC.

There are many open fundamental questions in particle physics. Three key science questions that the HL-LHC program will address are:

- What are the properties of the Higgs boson?
- Are there new particles and interactions beyond those predicted by the Standard Model?
- What is the nature of Dark Matter?

To answer these questions, researchers must compare theoretical predictions with observations of various rare processes, such as those involving the Higgs boson, that could be sensitive indicators of new physical phenomena. Discovering meaningful departures from theoretical predictions will require high precision measurements and the collection of a data sample more than two orders of magnitude larger than the one used for the Higgs discovery in 2012. To accomplish this, CERN plans to upgrade the accelerator, which will be renamed the High Luminosity-LHC, to deliver the high intensity proton beams required. In parallel, NSF proposes to fund the development of critical components of the ATLAS and CMS detectors that will allow them to record and analyze the torrent of data to be produced. The accelerator enhancements and the detector upgrades will be installed and commissioned during 2024-2026.

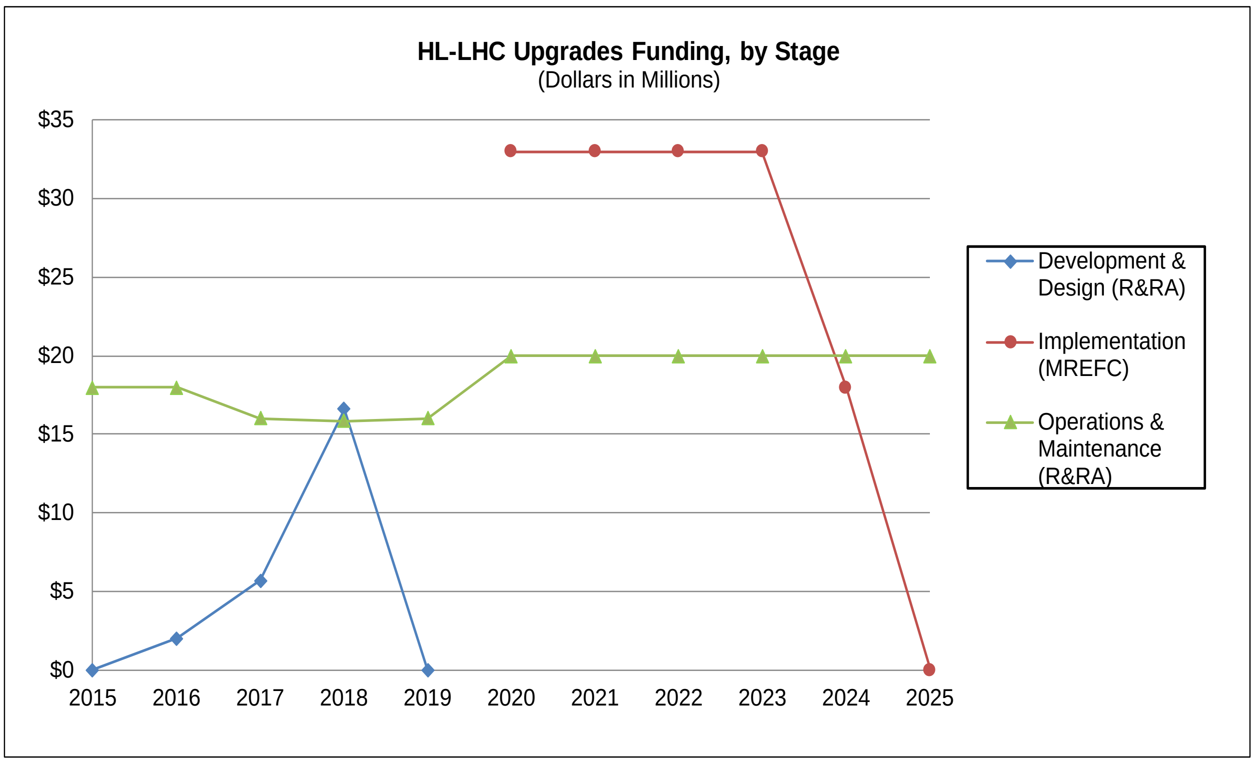
More than 50 funding agencies worldwide will contribute various components of the upgraded detectors, including significant contributions by DOE. NSF is working closely with DOE to coordinate development and design activities, as well as operational aspects of their mutual involvement in the operation of the ATLAS and CMS detectors. The HL-LHC will commence 10-years of operation in mid-2026 to produce more than 10-times the data collected by LHC operation through 2024.

Total Funding Requirements for HL-LHC Upgrades
(Dollars in Millions)

	Prior Years	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design[1]	$7.71	$16.60	-	-	-	-	-	-	-
Operations & Maintenance[2]		15.86	-	20.00	20.00	20.00	20.00	20.00	20.00
Subtotal, R&RA	$7.71	$32.46	-	$20.00	$20.00	$20.00	$20.00	$20.00	$20.00
MREFC:									
Implementation	-	-	-	33.00	33.00	33.00	33.00	18.00	-
Subtotal, MREFC	-	-	-	$33.00	$33.00	$33.00	$33.00	$18.00	-
TOTAL REQUIREMENTS	**$7.71**	**$32.46**	**-**	**$53.00**	**$53.00**	**$53.00**	**$53.00**	**$38.00**	**$20.00**

[1] The FY 2018 Actual reflects $7.50 million of forward funding for FY 2019 and FY 2020 HL-LHC development and design. No additional funds are expected in these years.

[2] O&M funding represents operations support for the current LHC facility and is forecast to remain constant during the HL-LHC upgrade. Installation, integration, and system testing of the upgraded detectors will be coordinated by CERN during 2024-2026. NSF's share of installation and commissioning costs is estimated at $5.0 million per detector, which will be funded from the FY 2024-2026 O&M budgets.



Management and Oversight

- NSF Structure: NSF oversight is handled by a program officer in the MPS Division of Physics (PHY). Cross-foundation coordination is provided by an integrated project team (IPT) that includes staff from the Office of the Director, Office of the General Counsel, Office of Legislative and Public Affairs, Office of the Assistant Director for MPS, OISE, EHR, and BFA. Within BFA, the Large Facilities Office and the Division of Acquisition and Cooperative Support provide advice to program staff and assists with agency oversight and assurance. The NSF program officer works closely with PHY colleagues overseeing the Experimental Particle Physics research program at NSF, and with counterparts in the DOE Office of High Energy Physics. Interagency coordination is accomplished through a Joint Oversight Group (JOG), which meets semi-annually. The framework for joint DOE/NSF oversight of the U.S.-led portion of the international ATLAS and CMS collaborations has a successful history spanning nearly two decades. It is based on an initial interagency memorandum of understanding implemented in December 1999 and superseded in March 2018 to encompass HL-LHC activities.

- External Structure: Columbia University (ATLAS) and Cornell University (CMS) will be the primary MREFC awardee institutions. NSF-funded principal investigators at Columbia and Cornell will be responsible for accomplishing the NSF-designated scope. NSF and DOE funded activities, which together form the U.S. collaboration for ATLAS and CMS, will be coordinated through the JOG as described above. The U.S. collaboration will coordinate with the international ATLAS and CMS project leadership to accomplish the entire upgrade program. The NSF construction scope for ATLAS and CMS was selected, at the outset of Conceptual Design, to be minimally coupled to other construction activities of DOE or international partners so that NSF's construction can be executed as two relatively independent projects within the overall scope of upgrade activities. NSF currently receives monthly technical status reports and quarterly financial reports of development and design activity and will receive monthly financial and technical status reports throughout construction. Revisions to the scope, budget, and schedule baselines will be reported to NSF, and revisions exceeding thresholds to be defined in the cooperative agreements for construction will require prior NSF approval.
- Interaction with CERN: In May 2015, DOE, NSF, and CERN executed a Cooperation Agreement concerning scientific and technical cooperation in nuclear and particle physics. The Cooperation Agreement establishes the framework under which DOE, NSF, and their awardees, as well as DOE national laboratories, will participate in the particle physics programs in the international ATLAS and CMS detector collaborations (under the auspices of CERN) in the era of the HL-LHC. Subject to availability of appropriated funds, NSF's total contributions to the HL-LHC upgrade program will be specified and incorporated under separate implementing arrangements in the form of addenda to the 2015 Cooperation Agreement. The CERN LHC Resources Review Boards (separate boards for ATLAS and CMS) are composed of representatives from each participating funding agency. The Boards monitor and oversee resource-related matters as defined by the framework for participation in each experiment. NSF is a full member of these LHC Resources Review Boards. The Boards meet semi-annually to approve all LHC upgrade planning at the international level.

Reviews

- Conceptual Design Reviews: March 2016 (ATLAS); March and April 2016 (CMS).
- Preliminary Design Reviews: January 2018 (ATLAS); December 2017 (CMS).
- Review of the Operations and Maintenance Plans of ATLAS and CMS for 2017-2021 (whose scope includes development and design activities for the detector upgrades): July 2016 (ATLAS); July 2016 (CMS).
- Department of Energy (DOE) Critical Decision 1 (CD-1) reviews: June 2018 (CMS); July 2018 (ATLAS). CD-1 approval marks the completion of the project definition phase and the conceptual design.
- Major subsystems of the combined international effort were scientifically and technically reviewed by the CERN LHC Committee (LHCC), an international committee of technical experts, followed by a cost and schedule review by the CERN Upgrade Cost Group, an international committee of technical and financial experts, which reported to the LHCC (July 2017-April 2018).

Project Status

PDR verified that all aspects of the technical scope are well defined. The flow-down from science to engineering requirements is sound and the lowest level requirements appear to be complete. Designs are capable of meeting performance requirements and are sufficiently mature that their risk-adjusted budgets may be confidently estimated. The Project Execution Plan (PEP) for each detector upgrade defines the construction responsibilities of the individual PIs and the awardee and subawardee university research groups. Each PEP documents the schedule and labor needed to accomplish these tasks. Each project has developed a credible resource-loaded schedule, defining the integration of these tasks and the logical sequence of work to be done.

During the Final Design phase, ATLAS and CMS will complete prototyping and preproduction testing of detector elements and electronic components. The PDR determined that the remaining engineering challenges are clearly defined and that the ATLAS and CMS development teams can meet them.

ATLAS and CMS will complete preparatory planning and enabling R&D with the goal of commencing construction in April 2020. NSF plans to hold Final Design Reviews of ATLAS and CMS around September 2019. In parallel, NSF will carry out a Cost Analysis informed by an Independent Cost Estimate review of the upgrades to confirm the validity of the construction-ready cost estimate for each detector.

Cost and Schedule

Funding for development and design was accomplished by redirecting $2.0 million per year from the LHC O&M budget in FY 2017-2019 and augmenting this amount with funding from the Division of Physics, including $7.50 million of forward funding from FY 2018 funds for FY 2019 and FY2020.

The planned April 2020 construction start date is dictated by the need to complete fabrication and delivery to CERN to meet the international integration schedule for 2024-2026. A significant delay could result in the transfer of critical NSF-funded scope to other international partners for accomplishment, resulting in lost leadership opportunities for U.S. scientists. NSF’s contributions to the ATLAS and CMS upgrades represent about six percent of the international detector upgrade program.

The MREFC project will be completed when the NSF-funded apparatus is delivered and passes component performance testing at CERN. Installation, integration, and system testing will be coordinated by CERN during 2024-2026. NSF’s share of installation and commissioning costs is estimated at $5.0 million per detector, which will be funded from the FY 2024-2026 O&M budgets. The annual O&M cost is forecast to remain constant during and following the HL-LHC upgrade installation.

Risks

Technical Risk: Technical designs are sufficiently mature to credibly support estimates of the costs to complete development and industrialization, and of construction. Remaining technical decisions during the Final Design stage have credibly bounded cost and schedule impacts. There are multiple alternatives for dealing with the remaining design uncertainties.

Deployment Risk: The MREFC project concludes with delivery and verification of subcomponent operability at CERN. CERN has overall responsibility for assembly, integration, and commissioning of the upgraded detectors, integrating the contributions from more than 40 different countries. While a slip in the CERN schedule will delay scientific research, it will not increase the cost of the NSF-funded construction. A significant delay may place schedule demands on NSF’s O&M beyond 2026.

Management Risk: The PDRs established that the ATLAS and CMS management teams are well-qualified. Their organizational structures and delegations of responsibility are appropriate for planning and construction. After reviewing evidence of high-quality cost estimating processes (as defined in the GAO Cost Estimating and Assessment Guide[2]), the PDR review panel reports expressed confidence that each

[2] www.gao.gov/new.items/d093sp.pdf

upgrade can be accomplished within its estimated TPC of $75.0 million. The construction schedules for each upgrade have realistic durations and are based on sound assumptions and methods. Conservative estimates of the time needed to accomplish critical tasks significantly mitigate the risk of incurring overall delay in completing construction, although there are opportunities for continued optimization of schedule risk that will be pursued during Final Design.

<u>Partnership Risk</u>: This activity supported through DOE and NSF research grants to universities, which creates a partnership risk where a potential shortfall in available research funding to one agency could impair the construction plans of the other. NSF and DOE plan to work closely in the lead-up to construction to regularly monitor and coordinate risk planning.

<u>Disposal Costs</u>: CERN's policy is to dispose of all irradiated detector components when they are no longer used in the detectors. Consequently, there are no anticipated costs to NSF at the end of operation.

Future Operations Costs

An additional agreement between NSF, DOE, and CERN ("Experiments Protocol II"), signed in December 2015, documents the responsibilities of U.S. participants to provide normal maintenance and operation of detector subsystems and components provided by NSF and DOE. Future MOUs with CERN will describe the distribution of tasks and other responsibilities for all participating institutions, including those supported by NSF, as well as the organizational, managerial, and financial guidelines to be followed by each detector collaboration. NSF anticipates providing approximately three percent of the total operation cost of the ATLAS and CMS detectors during HL-LHC operation (as it does today). This proportion is based on the number of NSF-supported scientists in each collaboration.

Data handling and computing costs are not yet established. A 10-fold increase in data rates would have dramatic consequences if dealt with using currently available technology. A well-orchestrated global effort is underway, progressing in parallel with the HL-LHC detector upgrades, to meet these needs. ATLAS and CMS are coordinating their efforts within this framework to seek common solutions. This improved coordination extends to the U.S. funding agencies, other funding agencies, and CERN. These efforts will coalesce into a planned 2020 HL-LHC Computing Technical Design Report, which will lay the foundation for a computing and data management system that will meet the requirements of the HL-LHC in 2026. NSF's support for the new system will come from within the approximately $10.0 million per year operational support it plans to provide each detector for O&M. In addition, NSF recently made a five-year, $25.0 million award to a consortium of 17 universities led by Princeton University to establish a software institute as a first step toward addressing the Big Data and computing challenges imposed by the data demands of the upgraded detectors.

LARGE SYNOPTIC SURVEY TELESCOPE (LSST) $46,340,000

The FY 2020 Request for the Large Synoptic Survey Telescope is $46.34 million. This is the seventh year of support for a nine-year construction project that began in August 2014. The NSB-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 Actual	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request	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 8.4-meter wide-field optical telescope designed to carry out surveys of nearly half 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 and Department of Energy (DOE) project to build an instrument that was ranked the top large ground-based astronomy project by the National Academies of Sciences, Engineering, and Medicine 2010 Astronomy and Astrophysics decadal survey: *New Worlds, New Horizons in Astronomy and Astrophysics*.[1]

Prior to NSF's construction award, NSF, DOE, and private (non-federal) partners invested over $130.0 million in LSST-related work. 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 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.

[1] www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics

Total Funding Requirements for LSST
(Dollars in Millions)

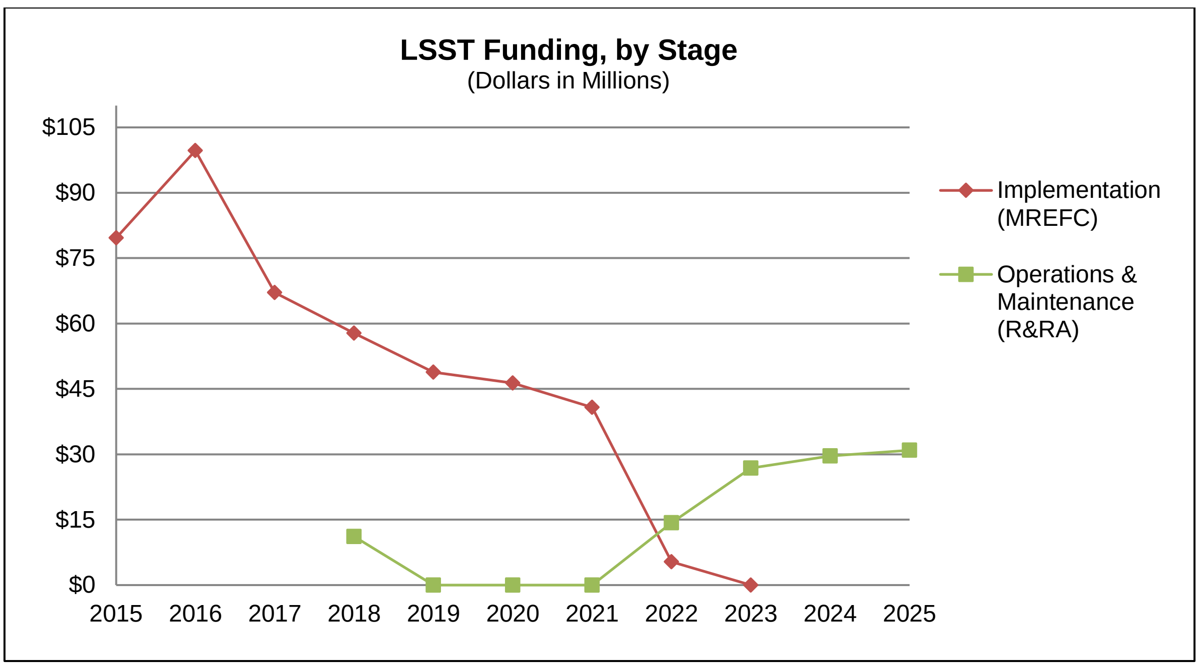
	Prior Years	FY 2018 Actual[1]	FY 2019 Estimate	FY 2020 Request	ESTIMATES[2] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design	$57.13	-	-	-	-	-	-	-	-
Operations & Maintenance[3]		11.10	-	-	-	14.32	26.85	29.64	30.93
Subtotal, R&RA	$57.13	$11.10	-	-	-	$14.32	$26.85	$29.64	$30.93
MREFC:									
Implementation[4]	273.93	57.80	48.82	46.34	40.75	5.36	-	-	-
Subtotal, MREFC	$273.93	$57.80	$48.82	$46.34	$40.75	$5.36	-	-	-
TOTAL REQUIREMENTS	**$331.06**	**$68.90**	**$48.82**	**$46.34**	**$40.75**	**$19.68**	**$26.85**	**$29.64**	**$30.93**

[1] FY 2018 obligations for Operations & Maintenance are intended to cover pre-operations costs for the first three years of the pre-operations ramp up, FY 2019-FY 2021.

[2] Outyear funding estimates are for planning purposes only.

[3] Operations & Maintenance funding represents NSF support only and amounts to about 49 percent of the operations cost. Other support from DOE and non-federal contributors provides the balance.

[4] Includes $4.74 million carried forward into FY 2019.



LSST Science Plan

The site on Cerro Pachón, Chile, was selected for LSST because of the excellent sky transparency and image quality, 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 data set of unprecedented 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. Estimates of

LSST's ability to locate Near-Earth Objects (NEOs) and Potentially Hazardous Asteroids (PHAs) have been refined by LSST project members[2], as well as by external studies, including an independent Jet Propulsion Laboratory study[3] 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 catalogue for objects larger than about 140 meters across should be about 75 percent complete for NEOs (about 80 percent for PHAs). Without LSST the completeness would be about 60 percent for NEOs (about 65 percent for PHAs).

LSST data will be widely accessible, and discovery opportunities will be available to K-12 students as easily as to professional astronomers. 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 data set 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 in Illinois.

Management and Oversight

- NSF Structure: NSF oversight is handled by a program officer in the MPS Division of Astronomical Sciences (AST) working cooperatively with NSF staff through the Integrated Project Team with members from MPS, BFA, the Office of General Counsel, the Office of Legislative and Public Affairs, OISE, and the Office of the Director. Within BFA, the Large Facilities Office provides advice to program staff and assists with agency oversight and assurance. 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. Interagency coordination is accomplished through weekly meetings of a Joint Oversight Group and was formalized through a Memorandum of Understanding 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 46 U.S. member institutions and 4 international affiliates as of February 28. 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 approval of NSF and DOE. AURA is also the responsible awardee for LSST pre-operations ramp-up activity that began in October 2018. AURA is responsible for coordinating construction activities and pre-operations activities that execute side-by-side.

Reviews

<ins>Technical Reviews</ins>: Reviews were conducted throughout the development and design 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.

<ins>Management, Cost, and Schedule Reviews</ins>: Cost, schedule, and risk are also scrutinized by the technical reviews. During construction, NSF and DOE hold regular joint progress reviews. The most recent reviews are summarized below:

- A successful data management-focused review took place in July 2017, providing support for significant use of cost contingency. The third joint agency progress review occurred in September 2017 and was successful. The latest joint agency progress review occurred in July/August 2018 and was also

[2] https://doi.org/10.1016/j.icarus.2017.11.033
[3] https://arxiv.org/abs/1705.06209

successful.

- Follow-up Earned Value Management surveillance reviews coincided with the 2017 and 2018 annual progress reviews.
- In January 2017, DOE and NSF held a joint external agency review of the project's plans for commissioning and transition to early operations. NSF and DOE followed up this review in August 2018 with another in-depth review of the project's advanced plans for commissioning as a significant extension of the annual progress review. The review panel praised the state of LSST commissioning plans.
- In December 2017, NSF and DOE held a joint review of the project's proposal for operations of the full ten-year survey, plus an additional four years of pre-operations ramp up and two years of post-survey activity. The review was successful, and NSF and DOE began initial funding of early pre-operations activity in FY 2019 (with NSF forward-funding from FY 2018 for the period FY 2019-FY 2021).

Project Status

NSF's construction award was issued in August 2014. As of January 2019, the project's MREFC scope is 66 percent complete. The primary telescope building has been completed, and dome installation and mirror cell lift construction are underway in earnest. About $100 million worth of components were successfully shipped or preparing for shipment to the site in 2018. The Auxiliary Telescope, used for calibration purposes, is being installed and commissioned. Progress on the LSST base facility located in La Serena, Chile, is progressing with no new risks that cannot be mitigated through the allocation of additional available contingency and is set to be completed in early to mid-year 2019. NSF- and DOE-supported activities remain tightly coordinated, both at the project level and between agency program officers.

Cost and Schedule

The FDR panel found the NSF Total Project Cost (TPC) of $473.0 million to be reasonable and justifiable, and they also recommended that the project introduce possible additional descoping options. NSF carried out further cost review prior to making the award. The LSST Project established a joint cost and schedule Monte Carlo (MC) method through their Project Management Control System and showed that the computed TPC corresponds to a better than 90 percent chance that the final cost of the current construction scope will fall within the NSB-approved funding cap and by the planned survey start date. This result was finalized in April 2015 and incorporated into the associated cooperative support agreement. In addition to NSF's contribution, DOE's baseline for the camera was fixed at $168.0 million. Construction also includes approximately $39 million from non-federal sources, all of which has been expended.

As of September 2018, the project had allocated 53 percent of the total contingency to the baseline, and $38.40 million of contingency remains. One recent change was for a 2.5-month schedule shift of the project finish date. The early finish is now in January 2022, reducing schedule contingency to 8.5 months, down from the starting contingency of 13 months. The 2018 annual integrated MC analysis was completed and indicates an 88 percent confidence that the project will be completed within the TPC of $473.0 million and a 90 percent confidence that the project will be completed by August 2022, one month ahead of the defined period of performance for construction. At the same time NSF and DOE work closely with the project to monitor and consider remaining descoping and deferral options.

Risks

Technical: Much of the technical risk was retired during development and design. 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 (DM) construction effort has been identified as a risk and re-planning has been completed. Implementation of the recommendations of the July 2017 DM review, including the release of cost and schedule contingency, has been completed. Careful planning to stage DM deliverables in coordination with commissioning sequencing will mitigate those risks associated with DM. Commissioning plans overall have pathfinders to mitigate technical risks as the entire system is assembled and integrated over the next two years.

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, noted in previous requests, was realized 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 history of an excellent 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: Significant attention has been paid to partnership risk, and that risk has been mitigated by careful coordination and unified project structures. The LSST project director oversees 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 agencies' program officers, grants officers, and financial managers.

Operations Costs

Operation costs are funded within R&RA. NSF is planning to support approximately half of operations funding with the balance coming from the DOE and non-federal, primarily international contributors. Operations costs are planning estimates based on the most recently available data. The overall 10-year operations cost estimate to NSF remains unchanged at $310.0 million (then-year U.S. dollars). The final full operations costs and the amount required from non-federal contributors will be determined through a review, approval, and award process that began with the project's submission of a formal proposal for the full LSST survey operations, including pre- and post-survey activities, in August 2017 and initial external panel review in December 2017. An additional proposal for the first three years of pre-operations ramp-up was received in May 2018 and covered costs through FY 2021. This proposal was reviewed and awarded in FY 2018 using FY 2018 R&RA funds to cover the entire proposed period. Additional O&M funds are not anticipated to be required in FY 2019 - 2021. The NSB is expected to review a request to authorize an operations award in FY 2020 or FY 2021, which will fund operations beginning in FY 2022.

In their joint memorandum of understanding, NSF and DOE agreed to fund operations, increasing agency support and revising the operations plans, as appropriate. AST is planning to provide approximately half of the original estimated steady-state amount, as well as operations ramp-up support, with the DOE Office of High Energy Physics providing one quarter, plus installation and commissioning support additional to the project construction cost. The project team has already established firm agreements to fund about half of the remaining one quarter with contributions from non-federal entities. Negotiations continue with potential partners to fund the remaining balance.

LSST from Gemini South at Sunset, August 2018. *Credit: Gianluca Lombardi*

REGIONAL CLASS RESEARCH VESSELS (RCRV) $0

No funding is requested in FY 2020 for construction of the Regional Class Research Vessel project. FY 2019 represents the final year in a 3-year funding profile within an NSB approved not-to-exceed total project cost of $353.97 million. In FY 2017, P.L. 115-31 appropriated $121.88 million to facilitate the planning and construction of three vessels. In FY 2018 P.L. 115-141 appropriated $105.0 million to continue construction of three vessels. In FY 2019, P.L. 116-6 appropriated $127.09 million, sufficient funding to complete construction of three vessels. This narrative provides an update on the project's status.

Appropriated and Requested MREFC Funds for the Regional Class Research Vessel Project
(Dollars in Millions)

FY 2017 Actual	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request	Total Project Cost
$121.88	$105.00	$127.09	-	$353.97

In justification of their recommendation to NSF for the construction of RCRV, the 2015 National Academies of Sciences, Engineering, and Medicine (the National Academies) report, *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*,[1] described eight high-priority science questions that 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).[2] In 2001, a report from the Federal Oceanographic Facilities Committee documented the need for 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 NSF-built Regional Class vessels to meet future science demand. In 2009, another National Academies report, Science at Sea, described the desirable characteristics of a modern Regional Class vessel. These characteristics and other science community factors were considered by the review panel when the preferred NAVSEA design was later down-selected. In 2012, NSF issued a solicitation for the refreshed design and potential construction of RCRV. Oregon State University (OSU) was selected and received the award in 2013. Input from external review panels,

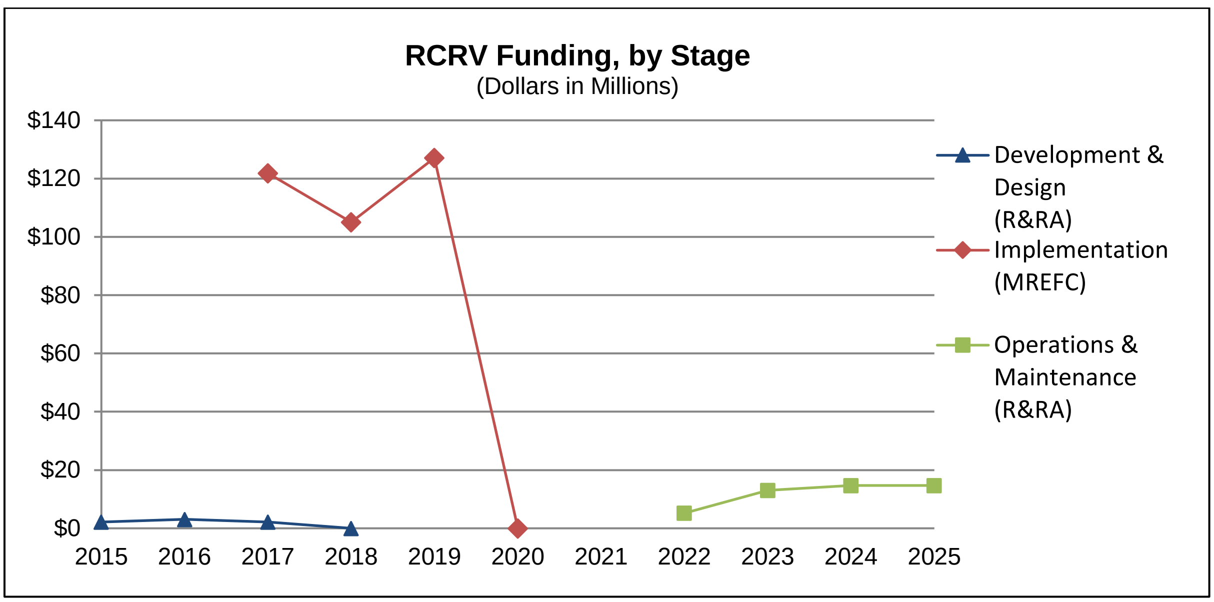
[1] The National Academies. Sea Change: 2015-2025 Decadal Survey of Ocean Sciences, 2015. www.nap.edu/read/21655/chapter/1
[2] National Ocean Council. Federal Oceanographic Fleet Status Report, 2013. https://obamawhitehouse.archives.gov/sites/default/files/federal_oceanographic_fleet_status_report.pdf

the University-National Oceanographic Laboratory System (UNOLS), and the National Academies *Sea Change* report, was received during the period 2013 to 2015 and informed the final decision to pursue construction. In 2015, the National Science Board authorized inclusion of funds to initiate construction for the RCRV project 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 was ready to advance to the construction stage. OSU awarded a contract for construction to Gulf Island Shipyards, Houma, LA. NSF plans to fund the operations of the RCRVs without increasing overall fleet costs, which is a result of fleet right-sizing and modernization.

Total Funding Requirements for RCRV
(Dollars in Millions)

	Prior Years	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request	ESTIMATES FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design	$11.93	-	-	-	-	-	-	-	-
Operations & Maintenance	-	-	-	-	-	5.20	13.07	14.70	14.70
Subtotal, R&RA	$11.93	-	-	-	-	$5.20	$13.07	$14.70	$14.70
MREFC:									
Implementation[1]	121.88	105.00	127.09	-	-	-	-	-	-
Subtotal, MREFC	$121.88	$105.00	$127.09	-	-	-	-	-	-
TOTAL REQUIREMENTS	**$133.81**	**$105.00**	**$127.09**	**-**	**-**	**$5.20**	**$13.07**	**$14.70**	**$14.70**

[1] FY 2018 Actual includes $17.0 million carried forward into FY 2019.



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 BFA Large Facilities Office, BFA Division of Acquisition and Cooperative Support, BFA Division of Institution and Award Support, Office of the Director, Office of the General Counsel, Office of the Assistant Director for Geosciences, and Office of Legislative and Public Affairs.

- External Structure: The RCRV project is funded through a series of cooperative agreements with OSU to manage the design refresh (conceptual, preliminary, and final designs), construction, testing and trials, and eventual operation of the first RCRV for the scientific community. The principal investigator for the award is the project 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 is a co-principal investigator on the award. The PM manages the core RCRV team including the risk manager, earned value management and schedule specialists, 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 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, and the National Oceanic and Atmospheric Administration) 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, which resulted in the selection of OSU as the lead institution for construction and ship operations.
- RCRV proceeded through the standard NSF processes that included a Conceptual Design Review (December 2013), Preliminary Design Review (August 2014) and Final Design Review (December 2016). The Final Design Review (FDR) ensured that anticipated project costs remained realistic and that no unforeseen events had arisen prior to the start of construction during FY 2017. The FDR Panel recommended that the project advance to the Construction Stage.
- Annual Progress Review: The first construction stage review was conducted in August 2018. Progress towards Design Verification and Transfer and OSU's management of the shipyard contract was evaluated. The panel expressed confidence that the OSU Team is well qualified, has extensive relevant experience in ship acquisition, has established a positive, professional working relationship with Gulf Island Shipyards, and is entirely capable of delivering up to three RCRVs, within budget and on schedule, that will meet mission requirements.

Project Status

As stated above, NSF selected OSU as the lead institution. A cooperative agreement was awarded to encompass the entire project, including tests and trials. The project is divided into four distinct phases, each to be funded through separate cooperative support agreements, 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 through eight)
- Phase IV: Transition to Operations (Years eight and nine)

The project completed Phase II in CY 2017, during which bids for construction of RCRV were solicited and evaluated from U.S. shipyards. The Phase III construction award with OSU has been made. Total estimated funding to OSU for RCRV through FY 2019 is $11.39 million in R&RA funds for development and design and $318.0 million in MREFC funds for construction. An additional $540,000 in R&A funding was obligated for other design costs. The remaining unobligated funding for the construction of three ships is $35.97 million, which is contingency held at NSF, for a total of $353.97 million in MREFC funding.

Cost and Schedule

The length of the project is projected to be nine fiscal years, including nine months of schedule contingency. Funding for the construction of RCRV from FY 2017 through FY 2020 supports the shipyard contract structure.

One significant enhancement to NSF oversight 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

Technical: The following technical risks are among the principal risks identified on OSU's project risk register. Planned mitigation strategies are included here with each identified risk. (1) Various situations may occur that could delay or add cost to OSU's management portion of the project. These include delayed appointments of key personnel, contracting issues, lack of management capacity due to optimistic planning, or misunderstanding of requirements. Contingency funds are included to increase OSU management capacity if needed. Approximately $2.80 million in contingency has been allocated to-date as a result of realizing this Project Management Capacity risk. (2) 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. (3) Growth in weight and vertical center of gravity has required design changes, namely lengthening by six feet, to ensure vessel seaworthiness. This is a typical risk for ship construction (and research vessels in particular) that requires active management by OSU and the shipyard, as well as oversight by NSF, such that the ship can operate safely and effectively. Approximately $5.10 million has been allocated to-date as a result of realizing this Weight and Stability risk. This risk is reduced by the re-design, but will not be entirely eliminated until the as-built ship is evaluated.

A science prioritized, time-phased de-scoping plan is in place (per NSF Large Facilities Manual, NSF17-066) to minimize impacts to science capabilities in 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. OSU included an estimate for the first year of operations beginning in 2022 using reasonable assumptions for escalations through 2021. They also assumed a robust but reasonable operating schedule of 200 days per year. OSU estimates each RCRV will cost $7.0 million to operate in its first full year, resulting in a rate of $35,000 per day, including technician support. This is comparable to the operation of current similar vessels after applying the appropriate cost escalation factors for size and complexity. NSF supports approximately 70 percent of the use of the U.S. Academic Research Fleet, which suggests RCRV is likely to cost NSF approximately $5.20 million in FY 2022, which is the first year the first two RCRVs transition into operations in the ARF. The ultimate annual cost of approximately $14.70 million for operating three RCRVs will be balanced by cost savings from reducing scope elsewhere in the Academic Research Fleet. A solicitation for operations of additional vessels beyond the first RCRV (R/V *Taani*) operated by OSU was released in January 2018. The The East Coast Oceanographic Consortium, whose members include URI, the Woods Hole Oceanographic Institution and the University of New Hampshire School of Marine Science and Ocean Engineering—along with 13 associate members, was selected to operate the second RCRV (R/V *Resolution*). Operator selection for the third RCRV will be made after the construction contract option is exercised.

Artist's rendition of the RCRV. *Credit: The Glosten Associates Inc.*

ORGANIZATIONAL EXCELLENCE $513,900,000

+$22,450,000 / 4.6%

Organizational Excellence Funding Summary
(Dollars in Millions)

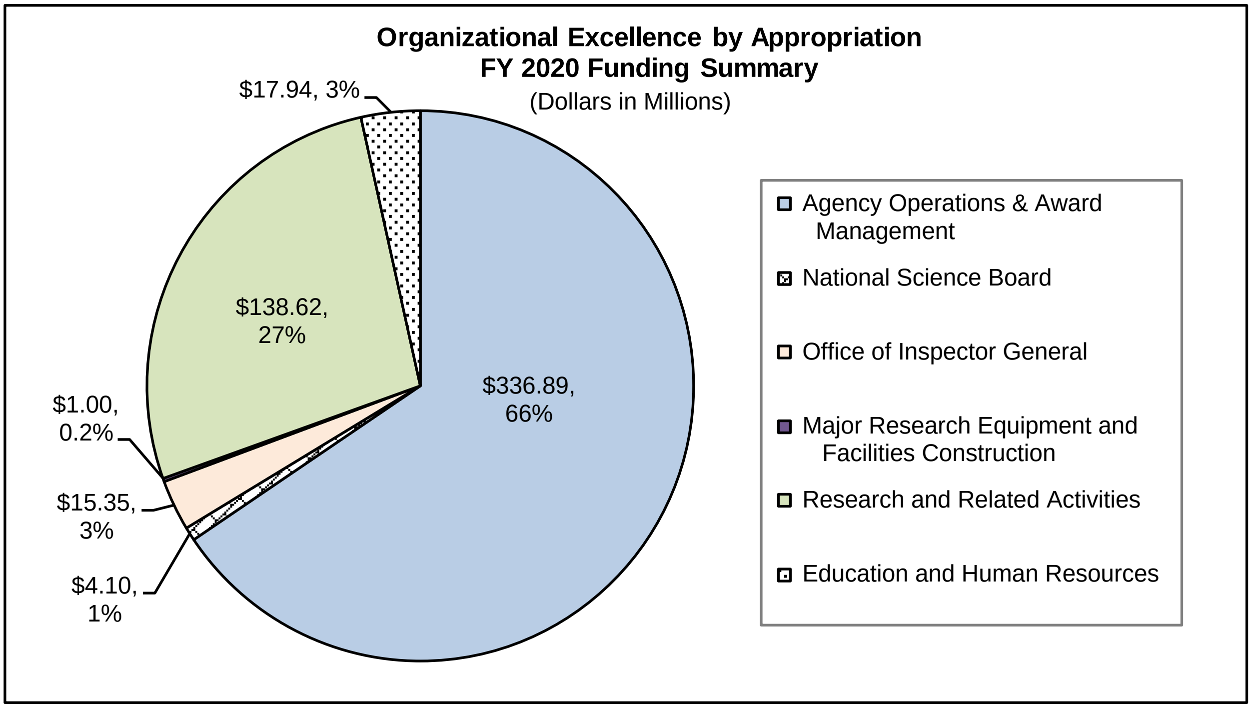
FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$491.45	-	$513.90	$22.45	4.6%

NSF's FY 2020 funding for Organizational Excellence is $513.90 million, this is about seven percent of the total NSF FY 2020 Request. NSF's management objectives have the goal of achieving organizational excellence through a continuous emphasis on efficiency and efficacy, as noted in NSF's Strategic Plan for 2018-2022[1] under Strategic Goal 3, Enhance NSF's Performance of its Mission. 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, Expand Knowledge in Science, Engineering and Learning, and Advance the Capability of the Nation to Meet Current and Future Challenges.

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 components—Human Capital, Travel, Information Technology (IT), Administrative Support, Major Research Equipment and Facility Construction (MREFC) Oversight, 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.

As part of its Agency Reform Plan, NSF launched its Renewing NSF initiative focusing on operational reforms in four areas: (1) make information technology work for us, (2) align NSF's workforce and work, (3) expand public and private partnerships, and (4) streamline, standardize, and simplify programs and processes. NSF will work to ensure that IT tools enhance employee productivity and satisfaction by enabling access to readily available, reliable, and fully integrated data that supports decision making. NSF will optimize the alignment of staffing and position descriptions with the changing landscape. NSF will maintain its already lean workforce through continuous improvements in personnel training and utilization, and through effective performance management. NSF will improve efficiencies in developing, implementing, and managing partnerships that maximize the scientific, economic, and societal impacts of its investments. NSF will also revise policies and business processes to increase standardization across NSF organizations and eliminate unnecessary complexity. These Agency reforms will allow NSF to continue to achieve its mission within a constantly evolving landscape in alignment with NSF's history of continued organizational improvement, and the Administration's government-wide agency reform activities as detailed in the President's Management Agenda (PMA).

[1] NSF (2018). Building the Future: Investing in Discovery and Innovation – NSF Strategic Plan for Fiscal Years (FY) 2018-2022. Retrieved from: www.nsf.gov/about/performance/strategic_plan.jsp



Organizational Excellence by Appropriation
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Agency Operations & Award Management	$328.51	-	$336.89	$8.38	2.6%
National Science Board	4.30	-	4.10	-0.20	-4.6%
Office of Inspector General	15.09	-	15.35	0.26	1.7%
Major Research Equipment and Facilities Construction	0.56	-	1.00	0.44	77.3%
Program Support Subtotal:	142.99	-	156.56	13.57	9.5%
Research and Related Activities	*126.73*	-	*138.62*	*11.89*	*9.4%*
Education and Human Resources	*16.26*	-	*17.94*	*1.68*	*10.3%*
Total	**$491.45**	**-**	**$513.90**	**$22.45**	**4.6%**

Organizational Excellence by Major Component

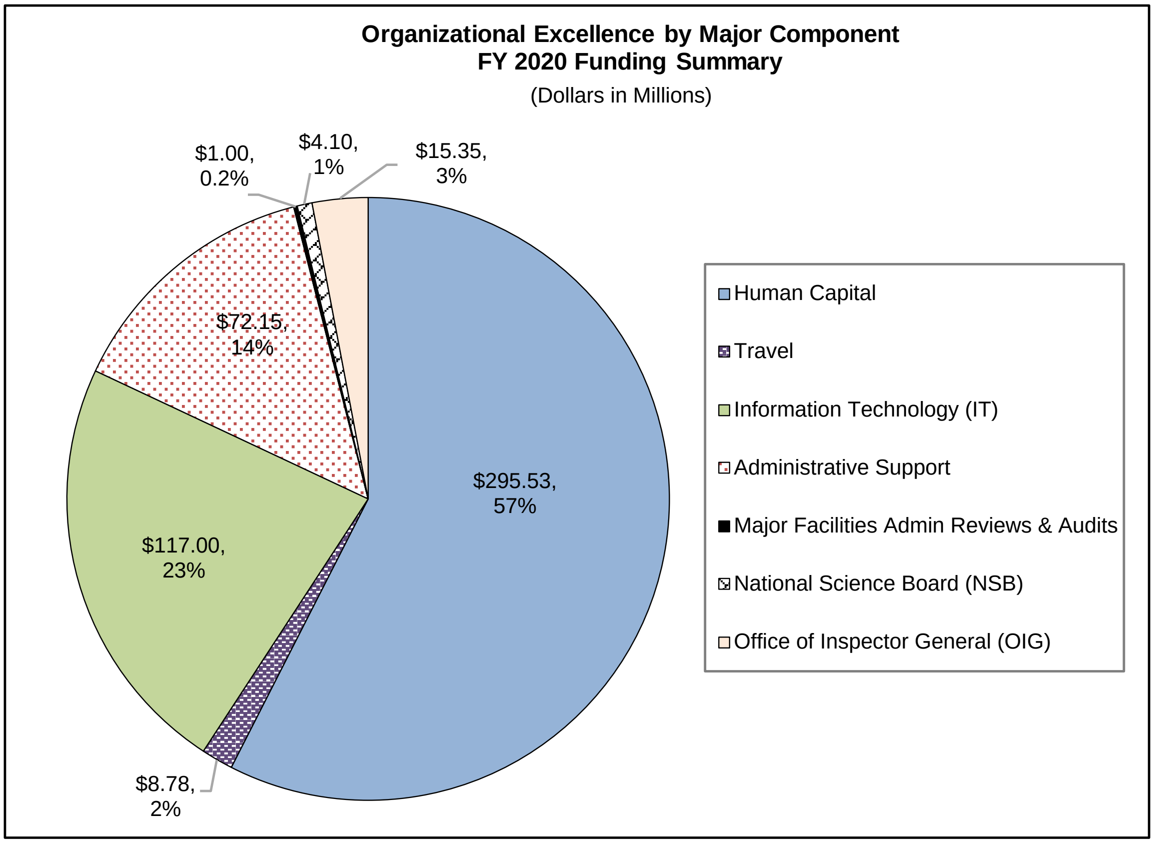
The table below shows the major components of Organizational Excellence. This table also shows the funding sources for the major components and activities, as several are funded through more than one appropriation.

Organizational Excellence by Major Component
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent	Funding Source
Human Capital	$277.18	-	$295.53	$18.34	6.6%	
Personnel Compensation & Benefits[1]	226.21	-	237.33	11.12	4.9%	AOAM
Management of Human Capital	6.84	-	8.53	1.69	24.7%	AOAM
IPA Appointments	44.13	-	49.66	5.53	12.5%	
Compensation	40.39	-	45.59	5.20	12.9%	RRA/EHR
Lost Consulting & Per Diem	3.74	-	4.07	0.33	8.8%	RRA/EHR
Travel	$8.17	-	$8.78	$0.61	7.4%	
NSF Federal Employee Staff	5.63	-	5.45	-0.18	-3.1%	AOAM
IPA Appointments	2.55	-	3.33	0.78	30.7%	RRA/EHR
Information Technology (IT)	$102.08	-	$117.00	$14.92	14.6%	
Agency Operations IT	20.87	-	24.29	3.42	16.4%	AOAM
Administrative Applications Services and Support	7.51	-	6.53	-0.98	-13.1%	AOAM
Administrative Infrastructure Services and Support	9.81	-	14.16	4.35	44.3%	AOAM
Administrative Security and Privacy Services and Support	3.03	-	3.09	0.06	1.9%	AOAM
Administrative IT Management	0.51	-	0.51	-	0.0%	AOAM
Program Related Technology (PRT)	81.21	-	92.71	11.50	14.2%	RRA/EHR
Mission-Related Applications Services	53.26	-	59.42	6.16	11.6%	RRA/EHR
Mission-Related IT Operations and Infrastructure	21.53	-	25.84	4.31	20.0%	RRA/EHR
Mission-Related Security and Privacy Services	4.18	-	5.22	1.04	24.9%	RRA/EHR
Mission-Related IT Management	2.24	-	2.24	-	0.0%	RRA/EHR
Administrative Support	$83.73	-	$72.15	-$11.59	-13.8%	
Space Rental	32.89	-	31.13	-1.77	-5.4%	AOAM
Operating Expenses	17.95	-	17.16	-0.80	-4.4%	AOAM
Building and Administrative Services	17.78	-	13.00	-4.78	-26.9%	AOAM
Other Program Related Administration	3.93	-	3.65	-0.28	-7.1%	RRA/EHR
Proposal Management Efficiencies[2]	1.33	-	-	-133.0%	-100.0%	RRA/EHR
E-Government Initiatives	1.46	-	1.33	-0.13	-8.6%	RRA/EHR
General Planning and Evaluation Activities	1.14	-	2.32	1.18	103.3%	RRA/EHR
Other Organizational Excellence Activities	11.17	-	7.21	-3.96	-35.5%	
Major Facilities Admin Reviews and Audits	0.74	-	0.36	-0.38	-51.4%	RRA-various
Evaluation and Assessment Capability	2.99	-	3.00	0.01	0.4%	RRA-IA
Public Access Initiative	3.50	-	1.75	-1.75	-50.0%	RRA-CISE
Planning and Policy Support	3.94	-	2.10	-1.84	-46.7%	RRA-IA
Major Facilities Admin Reviews and Audits	$0.56	-	$1.00	0.44	77.3%	MREFC
NSF Headquarters Relocation	$0.33	-	-	-0.33	-100.0%	AOAM
National Science Board (NSB)	$4.30	-	$4.10	-$0.20	-4.6%	NSB
Office of Inspector General (OIG)	$15.09	-	$15.35	$0.26	1.7%	OIG
Total	**$491.45**	**-**	**$513.90**	**$22.45**	**4.6%**	

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2018, $5.34 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $231.55 million. Approximately $4.19 million in ACRs are estimated for FY 2020 to meet the total PC&B requirement of $241.52 million.

[2] In FY 2019 Proposal Management Efficiencies moves from a line item under Other Program Related Adminisration to be part of Planning and Policy Support in the Integrative Activities (IA) budget activity.



1. Human Capital: The FY 2020 funding amount for Human Capital is $295.53 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 AOAM account while IPAs are funded through two programmatic accounts—R&RA and 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.

<u>NSF Workforce:</u>
The table below shows the agency's total workforce for FY 2020.

NSF Workforce
Full-Time Equivalents (FTE)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
AOAM FTE Allocation					
Regular	*1,315*	-	*1,315*	-	-
Pathways Intern[1]	*42*	-	*42*	-	-
Total, AOAM FTE Allocation	**1,357**	**-**	**1,357**	-	-
IPA FTE Allocation	*198*	-	*198*	-	-
AOAM FTE Usage (Actual/Projected)					
Regular	1,308	-	1,315	*7*	0.5%
Pathways Interns[1]	21	-	42	*21*	100.0%
Subtotal, AOAM FTE Usage	***1,329***	**-**	***1,357***	***28***	***2.1%***
Office of the Inspector General	68	-	68	-	-
Regular	*67*	-	*68*	*1*	*1.5%*
Pathways Interns[1]	*1*	-	-	*-1*	*-100.0%*
National Science Board	17	-	18	1	4.2%
Arctic Research Commission	3	-	3	-	-
Subtotal, Federal Employees FTE Usage	**1,417**	**-**	**1,446**	**29**	**2.0%**
IPA FTE Usage (Actual/Projected)	165	-	198	*33*	20.0%
Detailees to NSF	3	-	3	-	-
Total	**1,585**	**-**	**1,647**	**62**	**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 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: The FY 2020 Request for staff and IPA travel is $8.78 million. Staff travel accounts for about 62 percent of this total at a level of $5.45 million in FY 2020 and is provided from the AOAM account. Travel for IPA appointments, which is supported by the R&RA and EHR accounts, is $3.33 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: NSF's FY 2020 Request for IT investments total $117.0 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Agency Operations & Award Management (AOAM)	$20.87	-	$24.29	$3.42	16.4%
Program Related Technology (PRT)	81.21	-	92.71	11.50	14.2%
Research and Related Activities (R&RA)	*69.93*	-	*80.43*	*10.50*	*15.0%*
Education and Human Resources (EHR)	*11.28*	-	*12.28*	*1.00*	*8.9%*
Total	**$102.07**	**-**	**$117.00**	**$14.93**	**14.6%**

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 21 percent of NSF's total IT investment in the FY 2020 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 79 percent of NSF's FY 2020 Request for IT investments. More information on PRT can be found in the Program Accounts: R&RA and EHR chapter.

For FY 2020, funding for NSF's IT portfolio increases $14.93 million, or 14.6 percent. Investment priorities are strategically aligned with the PMA and will:

- Support the Agency's commitment to "Renewing NSF".
  - Accelerate necessary technology transformations geared toward improving the user experience both internally and for citizen-facing services. (Cross-Agency Priority (CAP) goal 4: Improving customer experience with federal services)
  - Support continued exploration of advanced technologies to support NSF's mission. (CAP goal 1: Modernize IT to increase productivity and security)
  - Employ innovative and advanced technology capabilities to transform the agency's workforce and amplify human performance. (CAP goal 3: Developing a workforce for the 21st century)
- Continuing support for the IT infrastructure and systems that support the administrative operations of the agency, leveraging converged infrastructure acquisitions to optimize systems and services for continued operation as an agile organization. (CAP goal 1: Modernize IT to increase productivity and security)
- Maintain the security of NSF's infrastructure to respond to the ever-evolving threat landscape and allocate a minimum of $202,165 to the FY 2020 operations and maintenance costs for Continuous Diagnostics and Mitigation (CDM) Phase 1 and Phase 2 tools and services. (CAP goal 1: Modernize IT to increase productivity and security)
- Support the continued operation of iTRAK, the Foundation's financial management system, and other mission systems to ensure continued interoperability and increase integration of NSF's core financial functions thereby increasing transparency and accuracy of reporting. (CAP goal 2: Leveraging data as a strategic asset)
- Support continued use and refinement of the Technology Business Management (TBM) framework for managing IT as a business. (CAP Goal 10: Improving outcomes through federal IT spending transparency)

4. Administrative Support: FY 2020 funding for Administrative Support is $71.79 million. The activities that comprise NSF's FY 2020 Administrative Support are:

- Space Rental at $31.13 million. More detailed information about Space Rental can be found in the AOAM chapter.
- Operating Expenses ($17.16 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 ($13.0 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 a $3.65 million to support general Planning and Evaluation activities, which include agency-wide efforts such as the verification and validation of performance information, and E-Government efforts. A detailed discussion about Other PRA can be found in the Program Accounts: R&RA and EHR chapter.
- Other Organizational Excellence Activities ($7.21 million) funds the Evaluation and Assessment Capability (EAC) and Planning and Policy Support—two NSF-wide activities managed by the Office of Integrative Activities. It also includes supported for the Public Access Initiative, an NSF-wide activity managed by the CISE. For more information on EAC, Planning and Policy Support, and Public Access Initiative, see the IA and CISE narratives respectively, in the RRA chapter.

5. Major Facilities Administrative Reviews and Audits: The FY 2020 Request includes $1.0 million within the MREFC account for oversight of NSF's major facility projects. For more information on this activity, see the MREFC chapter.

6. National Science Board: FY 2020 funding for the National Science Board (NSB) is $4.10 million. The staffing and operations of the NSB office are supported through a separate NSB appropriation. Details about the NSB FY 2020 Request can be found in the NSB chapter.

7. Office of Inspector General: FY 2020 funding for the Office of Inspector General (OIG) is $15.35 million. The staffing and operations of the OIG are supported through a separate OIG appropriation. Details about the OIG FY 2020 Request can be found in the OIG chapter.

NSF FY 2020 Request Funding for E-Government Initiatives

The tables below show NSF's contributions and service fees for various E-Government initiatives. Both the FY 2019 and FY 2020 levels are consistent with the funding amounts provided by the initiatives' respective managing partners.

NSF FY 2019 Request Funding for E-Government Initiatives

	FY 2019			Appropriations Account	
Initiative	Agency Contributions	Agency Svc. Fees	NSF Total	AOAM	R&RA
Grants.gov	$233,849	-	$233,849	-	$233,849
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	-	19,862	19,862	19,862	-
USA Jobs	-	10,350	10,350	10,350	-
E-Human Resource Integration	-	24,634	24,634	24,634	-
Integrated Acquisition Environment (IAE)	-	944,275	944,275	21,000	923,275
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	**$576,421**	**$1,868,228**	**$2,444,649**	**$944,953**	**$1,499,696**

LoB: Line of Business

NSF FY 2020 Request Funding for E-Government Initiatives

	FY 2020			Appropriations Account	
Initiative	Agency Contributions	Agency Svc. Fees	NSF Total	AOAM	R&RA
Grants.gov	$325,000	-	$325,000	-	$325,000
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	-	18,904	18,904	18,904	-
USA Jobs	-	10,399	10,399	10,399	-
E-Human Resource Integration	-	24,634	24,634	24,634	-
Integrated Acquisition Environment (IAE)	-	687,673	687,673	21,000	666,673
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	**$667,572**	**$1,610,717**	**$2,278,289**	**$944,044**	**$1,334,245**

LoB: Line of Business

IT Resource Statements

We jointly affirm that the Chief Information Officer (CIO) had a significant role in reviewing planned IT support for major programs and significant increases and decreases in IT resources reflected in this budget request.

Signed: Teresa Grancorvitz
Teresa Grancorvitz
Chief Financial Officer
National Science Foundation

Signed: D Aronson
Dorothy Aronson
Chief Information Officer
National Science Foundation

I affirm that I have collaborated with component Leadership and the Chief Financial Officer (CFO) on the IT Budget submission, and that IT includes appropriate estimates of all enterprise IT resources included in the budget request/President's Budget.

I affirm that I have reviewed and had significant input in approving all major IT Investments included in this budget request.

The CIO's common baseline rating for Element D ("D1. CIO reviews and approves major IT Investment portion of budget request") is: 3) Fully Implemented – Agency has developed and implemented its plan to ensure that all common baseline FITARA responsibilities are in place.

I affirm that I have reviewed and certified the use of incremental development practices, as appropriate, for the agency's IT investments.

Signed: D Aronson
Dorothy Aronson
Chief Information Officer
National Science Foundation

PROGRAM ACCOUNTS: RESEARCH AND RELATED ACTIVITIES (R&RA) AND EDUCATION AND HUMAN RESOURCES (EHR)

$156,560,000
+$13,570,000 / 9.5%

Funding from program accounts R&RA and EHR covers approximately 30 percent of the total Organizational Excellence portfolio. Three activities comprise program-funded Organizational Excellence: Intergovernmental Personnel Act costs, Program Related Administration, and Other Organizational Excellence Activities.

R&RA, EHR, and MREFC Organizational Excellence Funding Summary
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual	
				Amount	Percent
IPA Costs	**$46.68**	**-**	**$52.99**	**$6.31**	**13.5%**
IPA Compensation	40.39	-	45.59	5.20	12.9%
IPA Lost Consulting & Per Diem	3.74	-	4.07	0.33	8.8%
IPA Travel	2.55	-	3.33	0.78	30.7%
Program Related Administration	**$85.14**	**-**	**$96.36**	**$11.22**	**13.2%**
Program Related Technology	81.21	-	92.71	11.50	14.2%
Other Program Related Administration	3.93	-	3.65	-0.28	-7.1%
Other Organizational Excellence Activities	**$11.17**	**-**	**$7.21**	**-$3.96**	**-35.5%**
Major Facilities Admin Reviews and Audits	0.74	-	0.36	-0.38	-51.4%
Evaluation and Assessment Capability (EAC)	2.99	-	3.00	0.01	0.4%
Public Access Initiative	3.50	-	1.75	-1.75	-50.0%
Planning and Policy Support	3.94	-	2.10	-1.84	-46.7%
Total	**$142.99**	**-**	**$156.56**	**$13.57**	**9.5%**

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. Per policy released October 2016, NSF is continuing its pilot to require 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
IPA FTE Allocation	198	-	198	-	-
IPA FTE Usage (Actual/Projected)[1]	165	-	198	33	20.0%
Research and Related Activities (R&RA)					
IPA Compensation	$36.12	-	$41.09	$4.97	13.8%
IPA Per Diem	3.23	-	3.64	0.41	12.6%
Travel	2.35	-	3.08	0.73	31.2%
Subtotal, R&RA Costs	**$41.70**	**-**	**$47.81**	**$6.11**	**14.6%**
Education and Human Resources (EHR)					
IPA Compensation	4.27	-	4.50	0.23	5.4%
IPA Per Diem	0.51	-	0.43	-0.08	-15.4%
Travel	0.20	-	0.25	0.05	24.1%
Subtotal, EHR Costs	**$4.98**	**-**	**$5.18**	**$0.20**	**4.0%**
Total[1]	**$46.68**	**-**	**$52.99**	**$6.31**	**13.5%**

[1] FY 2018 includes IPA FTE utilization and costs for approximately one IPA FTE in the Office of Budget Finance and Award Management. For FY 2020, an IPA FTE usage of approximately 11 is included in the table above but the cost is budgeted within Other Program Administration and included in the General Planning and Evaluation (P&E) activities section of this narrative.

The FY 2020 funding for IPA costs is $52.99 million representing an IPA usage level of 198 FTE. This is the IPA FTE planning level used internally for allocations. In FY 2020, NSF is returning to prior practice of showing this IPA FTE planning level in the budget request rather than reflecting a number closer to the prior year utilization as was done uniquely in FY 2019. R&RA funding for IPAs is $47.81 million supporting 159 IPA FTE. EHR funding for IPAs is $5.18 million supporting 28 IPA FTE. For both R&RA and EHR, per IPA FTE costs are estimated at a level commensurate with the FY 2018 Actual.

The FY 2020 total IPA compensation is $45.59 million, per diem is $4.07 million, and travel is $3.33 million. Funding for these three categories is associated with full use of NSF's existing IPA FTE allocation and projected IPA costs for FY 2020. Costs increases are estimated based on projected IPA FTE utilization, current IPA funding, and the need to provide competitive salaries in order to recruit the best researchers in the science, technology, engineering, and mathematic fields.

Program Related Administration

Program Related Administration Investments
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Program Related Technology	$81.21	-	$92.71	$11.50	14.2%
Other Program Related Administration	3.93	-	3.65	-0.28	-7.1%
Total	**$85.14**	**-**	**$96.36**	**$11.22**	**13.2%**

The FY 2020 Request for Program Related Administration (PRA) is $96.36 million. PRA includes two categories of activities that support NSF's strategic goal, Enhance NSF's performance of its mission,[1] and that are directly funded from NSF's program accounts:

- Program Related Technology (PRT); and
- Other Program Related Administration (Other PRA)

Program Related Technology ($92.71 million)

Information technology (IT) investments funded through the R&RA and EHR accounts support NSF's mission activities and is approximately 79 percent of NSF's total IT investment portfolio. These programmatic investments are called Program Related Technology (PRT). NSF's FY 2020 level for PRT is $92.71 million. The remaining $24.29 million IT investment is funded through the AOAM account and is discussed in the AOAM chapter.

Program Related Technology Investments

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual	
				Amount	Percent
Mission-Related Applications and Services	$53.26	-	$59.42	$6.16	11.6%
Mission-Related IT Operations and Infrastructure	21.53	-	25.84	4.31	20.0%
Mission-Related Security and Privacy Services	4.18	-	5.22	1.04	24.9%
Mission-Related IT Management	2.24	-	2.24	-	-
Total	**$81.21**	**-**	**$92.71**	**$11.50**	**14.2%**

NSF accomplishes its mission by providing 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 2020, NSF's information technology priorities for PRT are strategically aligned with the President's Management Agenda (PMA) and will:

- Support the Agency's commitment to "Renewing NSF" with a broad focus on implementing and scaling solutions that will further PMA priorities. This investment will allow NSF to:
  - Accelerate necessary technology transformations geared toward improving the user experience both internally and for citizen-facing services. (Cross-Agency Priority (CAP) goal 4: Improving customer experience with federal services)
  - Support continued exploration of advanced technologies such as artificial intelligence (AI) and blockchain to support NSF's mission. (CAP goal 1: Modernize IT to increase productivity and security)
  - Employ innovative and advanced technology capabilities to transform the agency's workforce and amplify human performance. (CAP goal 3: Developing a workforce for the 21st century)
- Maintain the security of NSF's infrastructure to respond to the ever-evolving threat landscape. (CAP goal 1: Modernize IT to increase productivity and security)
- Support the continued operation of iTRAK, the Foundation's financial management system, to ensure continued interoperability with NSF's core financial functions. (CAP goal 2: Leveraging data as a strategic asset)
- Support the Financial Services Support investment, distinct from the iTRAK investment which supports core financials, to modernize NSF's financial management functions thereby increasing transparency

[1] NSF (2018). Building the Future: Investing in Discovery and Innovation – NSF Strategic Plan for Fiscal Years (FY) 2018-2022. Retrieved from: www.nsf.gov/about/performance/strategic_plan.jsp

and accuracy of reporting between NSF's core financial system (iTRAK) and other mission systems. (CAP goal 2: Leveraging data as a strategic asset)
- Support continued use and refinement of the Technology Business Management (TBM) framework for managing IT as a business. (CAP Goal 10: Improving outcomes through federal IT spending transparency)

Mission-Related Applications and Services ($59.42 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, a total of $45.02 million, which supports the following activities:
    - $24.45 million funds the operations and maintenance of NSF's mission support systems, which provide a suite of functionality supporting each stage in the NSF proposal and award management process. Work in this area incorporates ongoing needs for modernized functionality as it is incrementally deployed for production use.
    - $20.57 million for continuous modernization of systems and services that support the merit review process, such as:
        - Proposal Management Efficiencies ($13.71 million), prioritizing continuous modernization of citizen-facing services and data cleanup activities, enabling down-stream data analytics and opportunity for continued insertion of advanced technologies (such as AI) to enhance the merit review process. (CAP goals 1 and 4)
        - Public Access ($1.37 million) to enable the NSF Public Access Repository (NSF-PAR) to function as a controlled platform for integration with third-party services, leveraging application programming interfaces that support machine-to-machine communication to enhance use and discovery and reduce burden on the research community. (CAP goals 1, 2, and 4)
        - NSF.gov Content Management System modernization ($1.83 million) targeted for completion in FY 2020, improving content management for the citizen-facing NSF.gov website. (CAP goal 4)
        - $3.66 million for "Make IT Work for Us", accelerating integration of AI tools into the renewed merit review process. Specifically, NSF will work to consolidate and integrate functionality intended to reduce the burden on the user through the practical application of cutting-edge technologies such as AI and machine learning. In addition, NSF will leverage AI and machine learning to transform the agency's workforce, in parallel with technology transformations, ensuring the workforce remains relevant and has the necessary skillsets to evolve and meet the agency's future needs. (CAP goals 3 and 4)
- NSF's Data Management and Delivery investment, $6.13 million, centralizes and streamlines access to NSF data for agency staff, and provides analytical and visualization capabilities key to data-based decision making. NSF will prioritize efforts that continue to leverage AI and to evolve and mature data management and delivery capabilities that enable data-based policy making. (CAP goal 2)
- Funding for operations and maintenance of NSF's core financial system, iTRAK. The total FY 2020 investment for iTRAK is $7.90 million. Seventy percent of this request, $5.53 million, is funded by PRT and 30 percent is funded by AOAM. (CAP goal 2)
- Financial services support, $2.74 million, will enable account code structure modernization, largely impacting business mission-systems interfacing with iTRAK. (CAP goal 2)

Mission-Related IT Operations and Infrastructure ($25.84 million)
Investments in this category provide funding for operations and maintenance, as well as continuous modernization, of NSF's infrastructure, network, and telecommunications requirements. The FY 2020 level

rebalances the IT Portfolio to reflect investments in innovation focused on mission-related IT investments. Funding in this category will allow the agency to continue supporting technology transformations essential to taking advantage of increased cloud, platform and shared service offerings, enabling the agency to remain flexible to adapt to increasing demands. Investments, supporting CAP goals 1 and 10, include:

- Network ($8.11 million) - includes NSF's single network, with wired and Wi-Fi connectivity for NSF staff and visitors, and virtual meeting support.
- Data Center and Cloud ($4.47 million) - includes the resources necessary to support and monitor access to applications that enable execution of NSF's mission.
- End User ($5.49 million) - funds NSF's help desk services for internal users (NSF staff) and external users (the research community including institutions, principal investigators, reviewers, and NSF visitors), which are available 13 hours per day, five days per week; and, expanded automation and integration of the customer relationship management tool with asset and application management.
- Platform ($7.77 million) - reflecting NSF's use, management, and acquisition of hyper-converged hardware, software, and services. This funding level provides for optimal use and enables flexibility to meet NSF's evolving needs.

Mission-Related Security and Privacy Services ($5.22 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 2020 Request level will support operations and monitoring support for the Continuous Diagnostics and Monitoring (CDM) tools implemented thus far—including costs for tools and services received in Phases 1 and 2 of the CDM program—and to exploit the full capabilities of CDM offerings, enabling risk-based prioritization of the most significant cybersecurity improvements. (CAP goal 1)

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. In FY 2020, investments in this category will support continued use and refinement of the TBM framework, further enhancing the agency's ability to manage IT as a business. (CAP goal 10)

Other Program Related Administration ($3.65 million)
In FY 2020, $3.65 million for NSF's Other PRA includes funding for two Foundation-wide activities:

- NSF support for federal E-Government initiatives that are mission-related; and
- General planning and evaluation activities that are Foundation-wide.

Other Program Related Administration
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Proposal Management Efficiencies[1]	$1.33	-	-	-$1.33	-100.0%
E-Government Initiatives	1.46	-	1.33	-0.13	-8.6%
General Planning and Evaluation Activities	1.14	-	2.32	1.18	103.3%
Total	**$3.93**	**-**	**$3.65**	**-$0.28**	**-7.1%**

[1] In FY 2019 Proposal Management Efficiencies moves from a line item under Other Program Related Adminisration to be part of Planning and Policy Support in the Integrative Activities (IA) budget activity.

E-Government Initiatives ($1.33 million)
The FY 2020 funding level for NSF program-supported and mission-related E-Government initiatives is consistent with the FY 2020 funding amounts provided by the initiatives' respective managing partners. The FY 2020 funding level reflects changes for the following initiatives:

- The Integrated Award Environment initiative decreases approximately 27 percent based upon FY 2017 transaction data and the agreed upon funding algorithm;
- Grants.gov increases approximately 39 percent reflecting changes to the Grants.gov funding algorithm used to determine agency contributions and a built-in inflation rate of 2 percent.

General Planning and Evaluation Activities ($2.32 million)
FY 2020 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; approximately 11 IPA FTE in the office of Budget Finance and Award Management and the Office of the Director; and certain costs associated with the American Association for the Advancement of Science fellowships program. Also included is $104,020 for interagency management councils that support cross-agency management reforms and efficiencies, $91,782 for Cross-agency Priority (CAP) Goals, and $151,162 for the Department of State's Capital Security Cost Sharing (CSCS) and Maintenance Cost Sharing (MCS) programs. The FY 2020 funding level is based on the level of general planning and evaluation activities and projects that occurred in FY 2018 and anticipated activities for FY 2020.

Other Organizational Excellence Activities

Other Organizational Excellence Activities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Major Facilities Admin Reviews and Audits	$0.74	-	$0.36	-$0.38	-51.4%
Evaluation and Assessment Capability (EAC)	2.99	-	3.00	0.01	0.4%
Public Access Initiative	3.50	-	1.75	-1.75	-50.0%
Planning and Policy Support	3.94	-	2.10	-1.84	-46.7%
Total	**$11.17**	**-**	**$7.21**	**-$3.96**	**-35.5%**

Major Facilities Administrative Reviews and Audits ($360,000)
The projected administrative reviews and audits for major facilities to be funded via the R&RA account total $360,000 for FY 2020. This plan is based on the Annual Major Facilities Portfolio Risk Assessment conducted jointly by the Office of Budget, Finance, and Award Management in close coordination with Program. Besides risk, this assessment also considers event-driven oversight activities per CSB policy, which are based on American Innovation and Competitiveness Act (AICA) requirements as well as prior agreements with the Office of the Inspector General on the thresholds and frequency of certain audit activities.

Evaluation and Assessment Capability (EAC) ($3.0 million)
EAC is an integral part of NSF's operations. It supports, coordinates, and conducts NSF-wide program evaluations and evidence generation and utilization to catalyze learning and improvement through collaboration with NSF's directorates and offices. More detailed information on EAC can be found within the IA narrative in the R&RA chapter.

Public Access Initiative ($1.75 million)
The NSF Public Access Initiative seeks to make the results of NSF-funded research available to the greatest extent possible, pursuant to the memorandum on *Increasing Access to the Results of Federally Funded Scientific Research*, released by the Office of Science and Technology Policy (OSTP) on February 22, 2013, and consistent with NSF's mission and long-standing policies supporting data sharing. It will enable greater transparency and more access by more people to the results of NSF-funded research, and will provide for secure, predictable, and integrated management of publications, data, and other research products resulting from NSF funding.

Planning and Policy Support ($2.10 million)
Planning and Policy Support is a foundation-wide activity in the IA budget that supports select NSF-wide policy and planning activities. More detailed information on Planning and Policy Support can be found within the IA narrative in the R&RA chapter.

AGENCY OPERATIONS AND AWARD MANAGEMENT (AOAM) — $336,890,000 +$8,380,000 / 2.6%

Agency Operations and Award Management Funding Summary

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Personnel Compensation and Benefits[1]	$226.21	-	$237.33	$11.12	4.9%
Management of Human Capital	6.84	-	8.53	1.69	24.7%
Travel	5.63	-	5.45	-0.18	-3.1%
Information Technology	20.87	-	24.29	3.42	16.4%
Space Rental	32.89	-	31.13	-1.77	-5.4%
Operating Expenses	17.95	-	17.16	-0.80	-4.4%
Building and Administrative Services	17.78	-	13.00	-4.78	-26.9%
NSF HQ Relocation	0.33	-	-	-0.33	-100.0%
Total	**$328.51**	**-**	**$336.89**	**$8.38**	**2.6%**

[1] Funding levels for PC&B reflect direct appropriated funds only. In FY 2018, $5.34 million in Administrative Cost Recoveries (ACRs) were received bringing the total PC&B obligation to $231.55 million. Approximately $4.19 million are estimated for FY 2020 to meet the total PC&B requirement of $241.52 million.

Investments in the 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: Enhance NSF's performance of its mission.[1] AOAM's priorities are framed by two strategic objectives:

- Strategic Objective 1: Attract, retain, and empower a talented and diverse workforce; and
- Strategic Objective 2: Continually improve agency operations.

[1] NSF (2018). Building the Future: Investing in Discovery and Innovation – NSF Strategic Plan for Fiscal Years (FY) 2018-2022. Retrieved from: www.nsf.gov/about/performance/strategic_plan.jsp

NSF AOAM Workforce

AOAM NSF Workforce
(Full-Time Equivalent (FTE) and Other Staff)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
NSF AOAM FTE Allocation					
NSF AOAM -- Regular	1,315	-	1,315	-	-
NSF AOAM -- Pathways Intern	42	-	42	-	-
Total, FTE Allocation	**1,357**	-	**1,357**	**-**	**0.0%**
NSF AOAM FTE Usage (Actual/Projected)					
NSF AOAM -- Regular	1,308	-	1,315	7	0.5%
NSF AOAM -- Pathways Intern	21	-	42	21	1.00
Subtotal, FTE Usage	**1,329**	-	**1,357**	**28**	**2.1%**
Detailees to NSF	3	-	3	-	-
Total	**1,332**	**-**	**1,360**	**28**	**2.1%**

NSF's FY 2020 FTE allocation is 1,357. The FY 2020 FTE estimated usage is 1,315 regular and 42 Pathways FTE.

Personnel Compensation and Benefits (PC&B)

Personnel Compensation & Benefits
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Regular FTE Usage (projected)	*1,308*	-	*1,315*	*7*	*0.5%*
Student FTE Usage (projected)	*21*	-	*42*	*21*	*100.0%*
Regular FTE Base Salary	$173.70	-	$179.46	$5.76	3.3%
Student Salary	0.79	-	1.75	0.96	121.1%
Other Compensation[1]	1.47	-	1.70	0.23	15.6%
Awards	2.43	-	2.60	0.17	6.8%
Subtotal, FTE Compensation	**$178.40**	-	**$185.51**	**$7.11**	**4.0%**
Benefits	51.76	-	54.24	2.48	4.8%
Other Benefits[2]	1.39	-	1.77	0.38	27.1%
Subtotal, Benefits	**$53.15**	-	**$56.01**	**$2.86**	**5.4%**
COLA[3]	-	-	-	-	N/A
Total, PC&B	**231.55**	-	**241.52**	**$9.97**	**4.3%**
Source of Funds					
AOAM Appropriaton	$226.21	-	$237.33	$11.12	4.9%
Administrative Cost Recoveries[4]	5.34	-	4.19	-1.15	-21.5%
Total	**$231.55**	-	**241.52**	**$9.98**	**4.3%**

[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] FY 2020 reflects a pay freeze for civilian employeees.

[4] The ACR level for FY 2020 is estimated based on amounts received in FY 2018.

The FY 2020 Request for Personnel Compensation and Benefits (PC&B) is $241.52 million. Funding for PC&B reflects funding from two sources: $237.33 million in AOAM appropriated funds; and $4.19 million from Administrative Cost Recoveries (ACRs) estimated to be received during the year.

The PC&B cost estimate will support the projected FY 2020 year-end usage of 1,315 regular FTE employees, a total of 42 Pathways intern FTE, associated cost of benefits, general workforce performance awards (GWFPA), and Senior Executive Service (SES) bonuses. The FY 2020 Request for PC&B also contains $917,000 for the Federal Transit Benefits Program.

Included within this activity are funds targeted towards rewarding high-performing employees. NSF's approach for the allocation of these funds is still in development.

Management of Human Capital

Management of Human Capital
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual	
			Amount	Percent
$6.84	-	$8.53	$1.69	24.7%

The FY 2020 Request level for Management of Human Capital is $8.53 million. This level of funding will enable NSF to maintain operational support activities, training and development programs essential for NSF's permanent and rotator staff, and contractual support for human capital initiatives. FY 2020 investments align with Cross-Agency Priority (CAP) goal 3: Developing a workforce for the 21st century and support the following activities:

- Recruiting, hiring, and on-boarding of permanent and rotating staff, as well as processing support for pay, benefits, and incentive and other awards. The FY 2020 funding level ($2.73 million) is driven by reduced contract support for payroll, benefits, and time management activities.
- NSF's 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. FY 2020 funding ($700,000) reflects the rising costs of the Interior Business Center's shared services support for various critical personnel management systems.
- Strategic human capital support contracts on which NSF relies 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: Enhance NSF's performance of its mission, Strategic Objective 1: Human Capital - Attract, retain, and empower a talented and diverse workforce. FY 2020 funding ($1.53 million) reflects NSF's planned investment in business intelligence and other tools which are anticipated to reduce the cost of the contract support.
- 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 capacity-building activities including the NSF mentoring program, executive and supervisory training, and program management training. These training and development activities ($2.50 million) are designed to help ensure that the workforce, including permanent and rotating staff, as well as new supervisors and executives, are equipped with the tools needed to succeed as NSF employees.
- Workplace and work-life support ($920,000) provided for employees through NSF's health and family-friendly activities, including the health unit, employee assistance program, and child care subsidy.
- Outreach, career fairs, and other program support including activities such as the Federal Employees Viewpoint Survey ($150,000).

NSF Employee Travel

NSF Employee FTE Travel
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$5.63	-	$5.45	-$0.18	-3.1%

FY 2020 funding for NSF employee FTE travel is $5.45 million. NSF employee FTE travel is based on the travel activity associated with utilization of 1,315 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 2020 Request. Travel costs for IPA FTE are discussed in the Program Accounts: RRA and EHR narrative. A summary of total NSF travel is presented in the Organizational Excellence Overview.

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. A summary of total NSF IT is presented in the Organizational Excellence Overview.

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 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Support	$7.51	-	$6.53	-$0.98	-13.1%
Administrative IT Operations and Infrastructure	9.81	-	14.16	4.35	44.3%
Administrative Security and Privacy Services	3.03	-	3.09	0.06	1.9%
Administrative IT Management	0.51	-	0.51	-	-
Total	**$20.87**	**-**	**$24.29**	**$3.42**	**16.4%**

IT investments for agency operations ensure high quality, reliable, and secure administrative applications and associated IT infrastructure and provide the support and services necessary to meet the needs of the Foundation.

For FY 2020, NSF's information technology priorities for AOAM are strategically aligned with the President's Management Agenda (PMA) and include:

- Continuing support for the IT infrastructure and systems that support the administrative operations of the agency, leveraging converged infrastructure acquisitions to optimize systems and services for continued operation as an agile organization. (CAP goal 1: Modernize IT to increase productivity and security)
- Maintaining the security of NSF's infrastructure to respond to the ever-evolving threat landscape. (CAP goal 1: Modernize IT to increase productivity and security)

- Supporting the continued operation of iTRAK, the Foundation's financial management system, ensuring continued interoperability with NSF's core financial functions. (CAP goal 2: Leveraging data as a strategic asset)
- Support continued use and refinement of the Technology Business Management (TBM) framework for managing IT as a business. (CAP Goal 10: Improving outcomes through federal IT spending transparency)

<u>Administrative Applications Services and Support ($6.53 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 2020, the total request for iTRAK is $7.90 million. Seventy percent of this request will be funded by the R&RA and EHR accounts and 30 percent will be funded by the AOAM account. The AOAM portion of the FY 2020 funding level is $2.37 million and will fund operations and maintenance of the system. (CAP goal 2)
- Other administrative applications services funding is $2.97 million and will provide for operations and necessary technology refreshes for administrative and collaboration tools, such as SharePoint.
- A total of $1.19 million will provide 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 in alignment with NSF's Strategic Goal 3: Enhance NSF's performance of its mission, Strategic Objective 1: Human Capital - Attract, retain, and empower a talented and diverse workforce.

<u>Administrative IT Operations and Infrastructure ($14.16 million)</u>
Investments in this category support operations and maintenance, as well as continuous modernization, of ongoing activities that support administrative applications. The FY 2020 level rebalances the IT Portfolio to reflect investments in innovation focused on mission-related IT investments. Specifically, the investments in this category, supporting CAP goals 1 and 10, are classified as:

- Network ($3.30 million) - providing access to administrative applications and services via a single network with wired and Wi-Fi connectivity for NSF staff and visitors, and for virtual meeting support. This investment also includes voice services via NSF's modernized voice over IP (VoIP) solution.
- Data Center and Cloud ($2.07 million) - leveraging cloud offerings to continue reducing the footprint of NSF's single onsite data center, while enabling reliability and flexibility for future expansion. An additional $550,000 to support Data Center Facilities and Power is referenced in the Space Rental section of AOAM.
- End User ($6.59 million) - providing help desk services and customer care support for internal users (NSF staff), as well as support for mobile devices, workstations, and peripherals.
- Platform ($2.20 million) - reflecting NSF's use, management, and acquisition of hyper-converged hardware, software, and services. This funding level provides for optimal use and enables flexibility to meet NSF's evolving needs.

<u>Administrative Security and Privacy Services ($3.09 million)</u>
Investments in this category support the portion of NSF's IT security program related to administrative applications, which provides security and compliance oversight for NSF's entire IT portfolio. (CAP goal 1) The FY 2020 level rebalances the IT Portfolio to reflect investments in innovation focused on mission-related IT investments. The investment includes: offerings from the Continuous Diagnostics and Mitigation (CDM) program; automated configuration management tools that manage security patches and provide proactive protection from viruses, spyware, and other threats; application security; security control testing and tools; automated vulnerability assessment tools; and remediation and intrusion detection services.

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. In FY 2020, investments in this category will support continued use and refinement of the TBM framework, further enhancing the agency's ability to manage IT as a business. (CAP goal 10)

Space Rental

Space Rental
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$32.89	-	$31.13	-$1.77	-5.4%

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 NSF headquarters building in Alexandria is included.

In FY 2020, NSF will occupy over 700,000 square feet of space, primarily in one leased office building located in Alexandria, Virginia. The FY 2020 Request level for Space Rental is $31.13 million reflecting normal cost escalations which are offset by parking credits applied in FY 2020.

With the advanced capabilities afforded at NSF's new Alexandria, VA location, increased transparency into costs allows for additional reporting of IT expenditures related to NSF's onsite Information Technology Data Center. The portion of the total Space Rental cost aligned to the TBM cost pool for "Facilities and Power" is $550,000.

Operating Expenses

Operating Expenses
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$17.95	-	$17.16	-$0.80	-4.4%

The FY 2020 Request for Operating Expenses is $17.16 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 2020 Request for Operating Expenses include:

- A total of $8.01 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 1,315 projected for FY 2020.
- Oversight of large facilities including business systems reviews, contract close-out, and NSF outreach activities and materials ($1.80 million). At this level, NSF will suspend funding for the annual Large Facilities Workshop and associated Knowledge Sharing Gateway website that are used to coordinate and collaborate in the sharing of best management practices and lessons learned among large facilities.

- NSF's annual risk assessment, post-award monitoring desk reviews, post-award adjustment reviews, and documentation of the guidance and procedures for post-award monitoring processes ($1.75 million).
- Contract staff support ($1.75 million) in the Office of Budget, Finance, and Award Management, Division of Financial Management (BFA/DFM) to aid in accounting operations, financial statement and notes preparation, NSF property reporting, financial systems support and reporting, audit deficiencies resolution assistance, and travel audit review. Without this contract support, DFM would not be able to meet federal financial reporting requirements or audit requirements.
- NSF’s internal control quality assurance activities ($780,000): documenting, testing, and assessing internal control effectiveness, including effectiveness and efficiency of operations, reliability of financial reporting, and compliance with applicable laws and regulations.
- Extension of NSF’s system—Automated Acquisition Management Solution—for contract writing/E-procurement. FY 2020 funding ($470,000) includes licensing, subscription, deskside support, and training of new users on the system.
- Administrative grants processing duties ($390,000) including, processing funding actions, reviewing payment requests, and answering inquiries. In addition, funding is included for the review of information pertaining to the DATA Act reports
- System and related data analysis ($360,000) to continue to respond to evolving information needs to provide accurate, consistent information on financial data, funding rate, award size, and other statistics to NSF staff and the public. This information is disseminated via NSF’s Enterprise Information System, the Budget Internet Information System, and other reporting mechanisms.
- Review of grantee expenditures for unallowable costs, NSF’s grant accrual, and the Award Cash Management Service ($340,000). The results of these analyses are used to support NSF's post-award monitoring programs.
- A total of $250,000 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.
- Negotiation and issuance of indirect cost rates for a number of organizations for which NSF is the cognizant agency ($153,000).
- On-site, project management support to plan, coordinate, and execute NSF activities in connection with the Digital Accountability and Transparency Act responsibilities and operations ($145,000).
- A total of $107,000 provides support for the AOAM-funded portion of the Integrated Acquisition Environment, an e-government initiative managed by the General Services Administration; a contracting information online knowledge management resource; the printing and mailing of 1099 forms, a monthly download to update routing numbers in NSF’s financial system (iTRAK); and financial assistance award audit services to support incurred cost audits, accounting system audits, estimating system audits, and special projects which will provide NSF with information that will assist in the negotiation, award, administration, repricing, and settlement of large facilities financial assistance awards.
- Purchase card program oversight support ($90,000).

Building and Administrative Services

Building and Administrative Services
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Information Dissemination	$3.22	-	$2.52	-$0.70	-21.8%
Workplace Management	8.02	-	6.79	-1.23	-15.4%
Panel Support, Meeting Management, and Proposal Services	6.54	-	3.69	-2.85	-43.5%
Total	**$17.78**	**-**	**$13.00**	**-$4.78**	**-26.9%**

The FY 2020 Request level for building and administrative services is $13.0 million. This investment supports three sets of activities: information dissemination; workplace management; and panel support, meeting management, and proposal services.

<u>Information Dissemination ($2.52 million)</u>
Activities supported in this category align with CAP goal 4: Improving customer experience with federal services and include:

- Communications via web-based and other electronic information distribution tools that provide information to both the public and NSF staff regarding the NSF mission and related content. FY 2020 funding ($131,000) provides operations and maintenance for NSF's website and intranet, as well as user interface design.
- NSF website and business application development and user experience support. In FY 2020, a decrease (-$623,000, to a total of $1.31 million) will be achieved by reducing and streamlining contractor support as projects and initiatives are completed or rescaled.
- Graphic design ($450,000) includes the design and creation of layouts, graphics, animation, style sheets, and color schemes for use in NSF communications in print and on the web.
- Congressional Record and Code of Federal Regulations requests ($100,000) for the Foundation.
- Records management, and the establishment and execution of records management policies and procedures. FY 2020 funding ($530,000) supports the initial digitization of paper grant records, which will preserve the information for future agency use.

<u>Workplace Management ($6.79 million)</u>
This investment category supports a wide-range of activities including:

- 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; and personnel security adjudication support. FY 2020 funding ($3.35 million) reflects an increase of $751,000 for annual operations and maintenance support for NSF's visitor center and state-of-the-art security system and continuing implementation of a new NSF safety program that will reduce accidents, illness, injuries and fatalities by ensuring that hazards in the workplace are eliminated or controlled to the lowest level of risk. This increase is offset by a decrease of $170,000 achieved by reducing and streamlining contractor support for personnel security adjudications.
- Space management and facility operations, including development of space plans and assignments, space reconfigurations, and facility service and maintenance. FY 2020 funding ($1.29 million) reflects revised cost estimates based on current expenditures for building operations and maintenance at the Alexandria location.

- Activities related to property—the oversight and planning of mailroom, shipping and receiving operations, property receipt, inventory, and tracking. FY 2020 funding ($2.15 million) reflects revised cost estimates based on current expenditures at the Alexandria location.
- Sustainability reporting. FY 2020 funding (zero) eliminates contractor support for this activity.

Panel Support, Meeting Management, and Proposal Services ($3.69 million)
This category supports NSF's merit review process by providing various services for NSF staff, panelists, members of advisory committees, committees of visitors (COVs) and guests. Activities include:

- Management of central conference space, including activities to oversee, operate, and maintain mission-critical audiovisual and communications equipment and resources, both physical and virtual. FY 2020 funding ($1.10 million) provides the resources needed to schedule, coordinate and conduct NSF's onsite and virtual meetings and panels.
- Travel management and relocation services for NSF staff and panelists. FY 2020 funding ($1.45 million) supports iTRAK interface integration, business applications, and internal controls as well as Inspector General reporting and fiscal year-end processing.
- Management and support of all agency printing devices. FY 2020 funding ($940,000) for copier and printer maintenance and supplies reflecting current expenditures and an anticipated rate increase for the interagency agreement with the Government Printing Office.
- Elimination of the Proposal Processing Unit (-$2.24 million, to a total of zero). Central printing of proposals will be eliminated, and NSF's print shop will no longer be centrally funded by the AOAM account. Costs associated with print jobs will be charged back to the requesting NSF directorate/office or the job would need to be contracted out.
- NSF library support. A decrease (-$755,000, to a total of $206,000) will reduce librarian contractor support and the number of library subscriptions funded centrally through the AOAM account. Additional library subscriptions will be funded by directorates on an as-needed basis.

AOAM by Object Class

AOAM by Object Class
(Dollars in Thousands)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Personnel Compensation	$173,060	-	$181,321	$8,261	4.8%
Personnel Benefits	53,147	-	56,011	2,864	5.4%
Travel and Transportation of Persons	5,641	-	5,899	258	4.6%
Transportation of Things	373	-	385	12	3.2%
Rental Payments to GSA	27,014	-	25,233	-1,781	-6.6%
Rent to Others	1,699	-	222	-1,477	-86.9%
Communications, Utilities and Misc. Charges	478	-	2,850	2,372	496.2%
Printing and Reproduction	82	-	730	648	790.2%
Advisory and Assistance Services	43,916	-	42,351	-1,565	-3.6%
Other Services	12,188	-	9,885	-2,303	-18.9%
Purchases of Goods & Srvcs from Govt. Accts	6,844	-	7,473	629	9.2%
Operations and Maintenance of Facilities	-	-	8	8	N/A
Operations and Maintenance of Equipment	145	-	52	-93	-64.1%
Supplies and Materials	852	-	1,475	623	73.1%
Equipment	3,068	-	2,995	-73	-2.4%
Total	**$328,507**	**-**	**$336,890**	**$8,383**	**2.6%**

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.

AGENCY OPERATIONS AND AWARD MANAGEMENT

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; ~~$333,630,000:~~$336,890,000: *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 ~~2019~~2020 for maintenance and operation of facilities and for other services to be provided during the next fiscal year.

Agency Operations and Award Management
FY 2020 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 2018 Appropriation	$328.51	0.41	-$0.19	-$0.22	-	$328.51
FY 2019 Annnualized CR	328.51	0.19				328.70
FY 2019 Enacted	329.54					329.54
FY 2020 Request	336.89					336.89
$ Change from FY 2019 Enacted						$7.35
% Change from FY 2019 Enacted						2.2%

Explanation of Carryover

Within the Agency Operations and Award Management (AOAM) no-year component, $189,091 was carried over into FY 2019.

NSF Headquarters Relocation

- Amount: $49,191
- Reason: Resources reserved for unanticipated expenses related to the new NSF Headquarters.
- Obligation: FY 2019 Quarter 1

The remaining $139,900 consists of funds that were not ready for obligation in FY 2018.

NATIONAL SCIENCE BOARD (NSB) **$4,104,000**

-$193,000 / -4.5%

The FY 2020 Budget Request for the National Science Board is $4.10 million, which is a decrease of $193,000 from the FY 2018 Actual of $4.30 million. This FY 2020 Request level will enable the Board to fulfill its policymaking and oversight responsibilities for NSF and continue its statutory responsibilities as outlined in the Organic Act, including activities related to the authorization of major research facilities projects.

NSB Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total, NSB	**$4.30**	**$4.37**	**$4.37**	**$4.10**	**-$0.19**	**-4.5%**
Full-Time Equivalents (FTEs)	17	18	18	18	1	5.9%

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.), ~~$4,320,000:~~$4,100,000: *Provided*, That not to exceed $2,500 shall be available for official reception and representation expenses.

National Science Board
FY 2020 Summary Statement
(Dollars in Millions)

	Enacted/ Request	Expired	Obligations Actual/ Estimates
FY 2018 Appropriation	$4.37	-$0.07	$4.30
FY 2019 Annualized CR	4.37		4.37
FY 2019 Enacted	4.37		4.37
FY 2020 Request	4.10		4.10
$ Change from FY 2019 Enacted			-$0.27
% Change from FY 2019 Enacted			-6.2%

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 at least 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; oversee the lifecycle of large facilities, including conducting site visits; and address significant S&E-related national policy issues. The Board initiates and conducts studies and reports on a range of policy topics and engages NSF's stakeholders nation-wide. 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 publications have examined topics such as building a science, technology, engineering, and mathematics (STEM)-capable workforce; the rise of China in S&E; operations and maintenance costs for NSF's large facilities; and mid-scale research infrastructure. Currently, the NSB is undertaking an effort to set a Vision for NSF for 2030.

The Board has several standing committees, and an *ad hoc* task force on the Skilled Technical Workforce to assist with its responsibilities.

The **Executive Committee** (EC) includes the Director of NSF, who chairs the Committee, and four elected members from the Board, of whom two are the NSB Chair and Vice-Chair. The Board has delegated to this Committee its authority to approve awards in the rare instances when immediate action is required between Board meetings.

The **Committee on Oversight** (CO) 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.

The **Committee on Strategy** (CS) 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.

The **Committee on National S&E Policy** (SEP) 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 (NCSES); 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.

The **Committee on Awards and Facilities** (A&F) addresses strategic issues and recommends policies to the Board related to awards and Major Research Equipment and Facilities Construction (MREFC) projects; makes recommendations to the Board on awards and facilities; and provides lifecycle oversight on facilities and oversight on awards.

The **Committee on External Engagement** (EE) 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 S&E.

The **Subcommittee on Honorary Awards** (AWD) reviews nominations for two awards established by the Board: the Vannevar Bush Award and the Public Service Award.

The **Task Force on Skilled Technical Workforce** (STW), which was created in November 2017, identifies opportunities and challenges facing students, businesses, educators, and other STW stakeholders and recommends strategies and policies for strengthening the skilled technical workforce.

Ongoing activities of the Board include review and approval of:

- Large awards, MREFC projects and other proposals as needed;
- NSF's Management Response to the Office of Inspector General (OIG) Semi-annual Reports to Congress;
- Transmittal of the NSF, OIG, and NSB budget submissions to the Office of Management and Budget;
- Priority order of projects in the MREFC Account; and
- Inclusion of new projects requiring funding under the MREFC Account.

The Board also reviews and makes recommendations on:

- NSF's financial management reports;
- The operation of NSF's merit review system; and
- NSF's research infrastructure portfolio.

Office of the National Science Board
Personnel Compensation and Benefits and Other Operating Expenses
(Dollars in Thousands)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2020 Request	Change Over FY 2020 Actual Amount	Percent
Personnel Compensation Benefits (PC&B)[1]	$3,078	-	$3,149	$71	2.3%
Staff Development and Training	21	-	38	17	81.0%
Advisory and Assistance Services	785	-	600	185	-23.6%
Travel and Transportation of Persons	260	-	214	46	-17.7%
Communications, Supplies, and Equipment	150	-	100	50	-33.3%
Representation Costs	3	-	3	-	N/A
Total, NSB	**$4,297**	**$4,370**	**$4,104**	**$193**	**-4.5%**
Full-Time Equivalent	17	18	18	1	5.9%

[1] FY 2020 PC&B includes base salary costs and anticipated within grade and promotion increases.

Personnel Compensation and Benefits

The Board's FY 2020 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 developing 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 some of the resources needed to produce reports such as the Congressionally-mandated *Science and Engineering Indicators*. In recent years, the Board has created interactive digital products to facilitate accessibility and use of *Indicators* data in policy decisions and analysis. *Indicators 2016* was the first fully digital version of the report. The latest edition of *Indicators*, which was released in January 2018, included a state data tool that allows for more frequent and timely updates and state one-pagers that highlight select data by state. At the recent request of Congress, the Board produced reports on operations and maintenance costs for NSF facilities and funding for mid-scale research infrastructure.

Other items in the Advisory and Assistance Services line support multimedia strategies, such as data-driven dynamic graphics, film, and video, to increase awareness and use of the Board's products by stakeholders. This budget line also supports maintenance of an electronic official records management system, which enables compliance with federal records requirements; the webcasting and archiving of all open Board meetings; transcription services necessary for compliance with the *Government in the Sunshine Act*; and board book management software which facilitates effective and efficient NSB meetings.

The NSB's Travel and Transportation of Persons budget line primarily covers costs related to Board member travel to NSF headquarters for the Board's four annual meetings and a member-only retreat, for oversight of NSF's large programs and facilities, and for engaging stakeholders. In conjunction with the release of *Indicators 2018,* for example, the Administration, Congress, and scientific societies requested a greater number of briefings by Board members than in previous years. Recently, the Board organized listening sessions in Washington DC, Virginia, and South Carolina to explore the challenges and opportunities facing the skilled technical workforce. Also supported in this budget line is travel for invited speakers and participants in the NSB's activities, such as a panel on the future of fundamental S&E research that the Board organized at its February 2019 meeting.

The Communications, Supplies, and Equipment budget line funds communications services and information technology.

The FY 2020 Budget Request will support the Board's efforts to strengthen the U.S. S&E 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 NCSES) 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)

$15,350,000
+$263,000 / 1.7%

The Appropriations Act that funds the National Science Foundation contains a separate appropriation for NSF's Office of Inspector General. Accordingly, this FY 2020 OMB 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 2020 Budget Request for OIG is $15.35 million, an increase of $263,000 over the FY 2018 Actual of $15.09 million.

OIG Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total, OIG	**$15.09**	**$15.20**	**$15.35**	**$15.35**	**$0.26**	**1.7%**
Full-Time Equivalents (FTEs)	68	71	71	68	-	-

Appropriations Language

For necessary expenses of the Office of Inspector General as authorized by the Inspector General Act of 1978, $15,350,000, of which $400,000 shall remain available until September 30, ~~2020.~~2021.

FY 2020 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 2018 Appropriation	$15.20	$0.39	-$0.40	-$0.10	$15.09
FY 2019 Annualized CR	15.20	0.40			15.60
FY 2019 Enacted	15.35				15.35
FY 2020 Request	15.35				15.35
$ Change from FY 2019 Enacted					-
% Change from FY 2019 Enacted					N/A

Explanation of Carryover

Within the Office of Inspector General (OIG) two-year account, $400,000 was carried over into FY 2019.

Office of the Inspector General

- Amount: $400,000
- Reason: Funds are expected to be used to procure financial and forensic audit services. 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.
- Obligation: Anticipated FY 2019 Quarter 4

OIG Responsibilities and Structure

OIG provides independent oversight of NSF's programs and operations. The office promotes effectiveness, efficiency, and economy in administering the Foundation's programs and prevents and detects fraud, waste, and abuse within NSF or by individuals who receive NSF funding. By statute, NSF OIG is organizationally independent from the agency, with the Inspector General (IG) reporting directly to the National Science Board and Congress. Given the geographic breadth of the projects NSF funds, OIG conducts audits and investigations across the continental U.S., Alaska, Hawaii, Puerto Rico, and Antarctica. To fulfill its important mission, OIG employs a diverse staff of scientists, attorneys, certified public accountants, criminal investigators, management analysts, data analysts, and information technology specialists. OIG's FY 2018 appropriation was just 0.2 percent of NSF's appropriation and 0.05 percent of NSF's $29.8 billion portfolio of active awards, yet its return on investment is many times that amount. OIG serves as an invaluable safeguard against fraud, waste, abuse, and whistleblower reprisal.

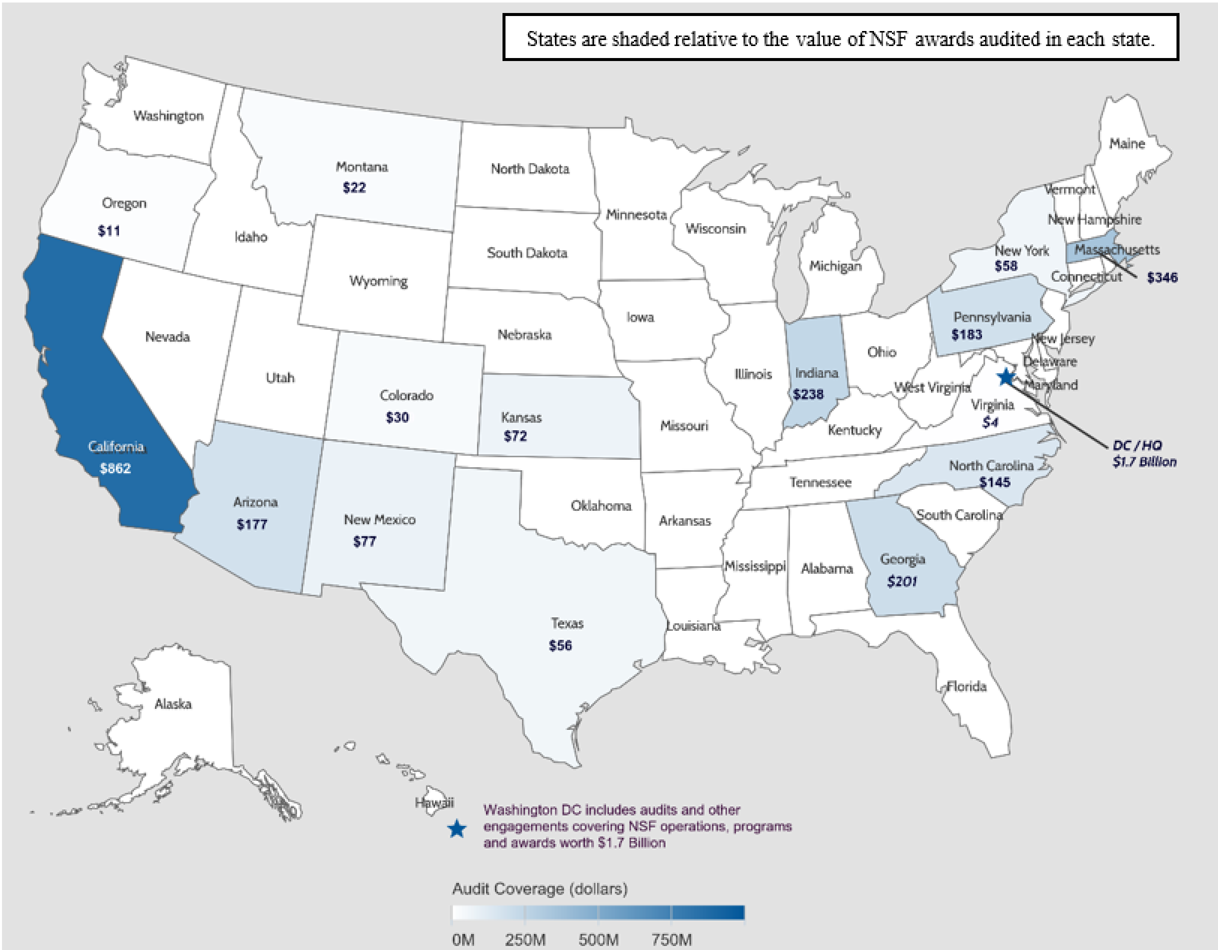
OIG's work is divided into two functional areas: the Office of Audits and the Office of Investigations, which are supported by the Office of Management, Office of Counsel, and Immediate Office of the Inspector General. Highlights of the office's operational impact and strategic focus by functional area follow:

Audit Impact and Strategic Focus

OIG's Office of Audits (OA) conducts audits of NSF's contracts, cooperative agreements, and grants to universities and other research institutions, as well as internal audits of NSF's programs. These audits help ensure that financial, administrative, and programmatic activities are conducted economically, effectively, and in compliance with applicable regulations.

In FYs 2017–2018, OIG audited $4.2 billion in NSF funding in 15 states and Washington, D.C. — resulting in 34 audit and other engagement reports containing a total of $5.1 million in questioned costs and 232 recommendations to improve NSF operations. The map below shows the value of the awards audited in each state.

Audit Coverage October 2016 – September 2018



In FY 2018, OA identified more than $1.32 million in questioned costs and made 101 recommendations to NSF and its awardees to strengthen program and grant operations. NSF has already taken, or committed to take, corrective actions for 40 of the 101 recommendations. In addition to recouping questioned costs, implemented recommendations from recent OIG audits have helped strengthen NSF's records management, oversight of conference spending, and controls over its large-scale, multi-user research facilities (major facilities).

Much of OA's work is focused on recipients of NSF's oversight of major facilities, which are state-of-the art infrastructure including telescopes, ships, and observatories. As of November 2018, NSF supported 25 major facilities, each of which cost between $70 million and $800 million to construct. NSF also spends approximately $1 billion a year on major facility operations. Since 2010, OIG has issued 61 reports containing 151 recommendations to improve NSF's management of major facility construction and operations. To date, NSF has addressed 145 of these recommendations. Additionally, Congress relied on these audit reports and recommendations to codify several major facility-focused requirements in the *American Innovation and Competitiveness Act of 2017* (AICA).

OA is currently conducting an audit to determine whether NSF, as part of its oversight of the construction and operations of major facility projects, has internal controls that ensure awardees allocate their construction and operation expenses to the correct award. Ensuring that strong controls exist over the use of such funds is vital, as the use of operations funds for construction work can hide cost overruns and deplete funding needed for the operations phase. OA's plans for continuing oversight of major facilities include:

- Assessing how NSF identifies, plans for, and manages essential divestment opportunities for major facilities. The AICA requires NSF to plan for the full lifecycle of a major facility, including costs associated with divestment of a facility at the end of a lifecycle. OA also plans to monitor NSF's actions in response to the AICA.
- Auditing NSF's oversight of awardee reporting of program income and its use of contractors to assess the impacts of its scientific investments.
- Monitoring the design, construction, and ongoing capital investment and support of the Antarctic Infrastructure Modernization for Science (AIMS), one of NSF's most challenging major facility initiatives. According to NSF, the AIMS project will ensure that McMurdo Station remains a viable platform for supporting Antarctic science for the next 35 to 50 years.

In addition to discretionary audits, OIG oversees the audit of NSF's annual financial statements, annual audits mandated by the *Federal Information Security Modernization Act of 2014* (FISMA), the *Improper Payments Elimination and Recovery Act* (IPERA), biennial audits mandated by the *Digital Accountability and Transparency Act* (DATA Act), and triennial audits mandated by the *Government in the Sunshine Act of 1976*. Additionally, in FY 2019, OIG is required to review NSF's fleet utilization, and may begin work to comply with the *Grants Oversight and New Efficiency* (GONE) Act.

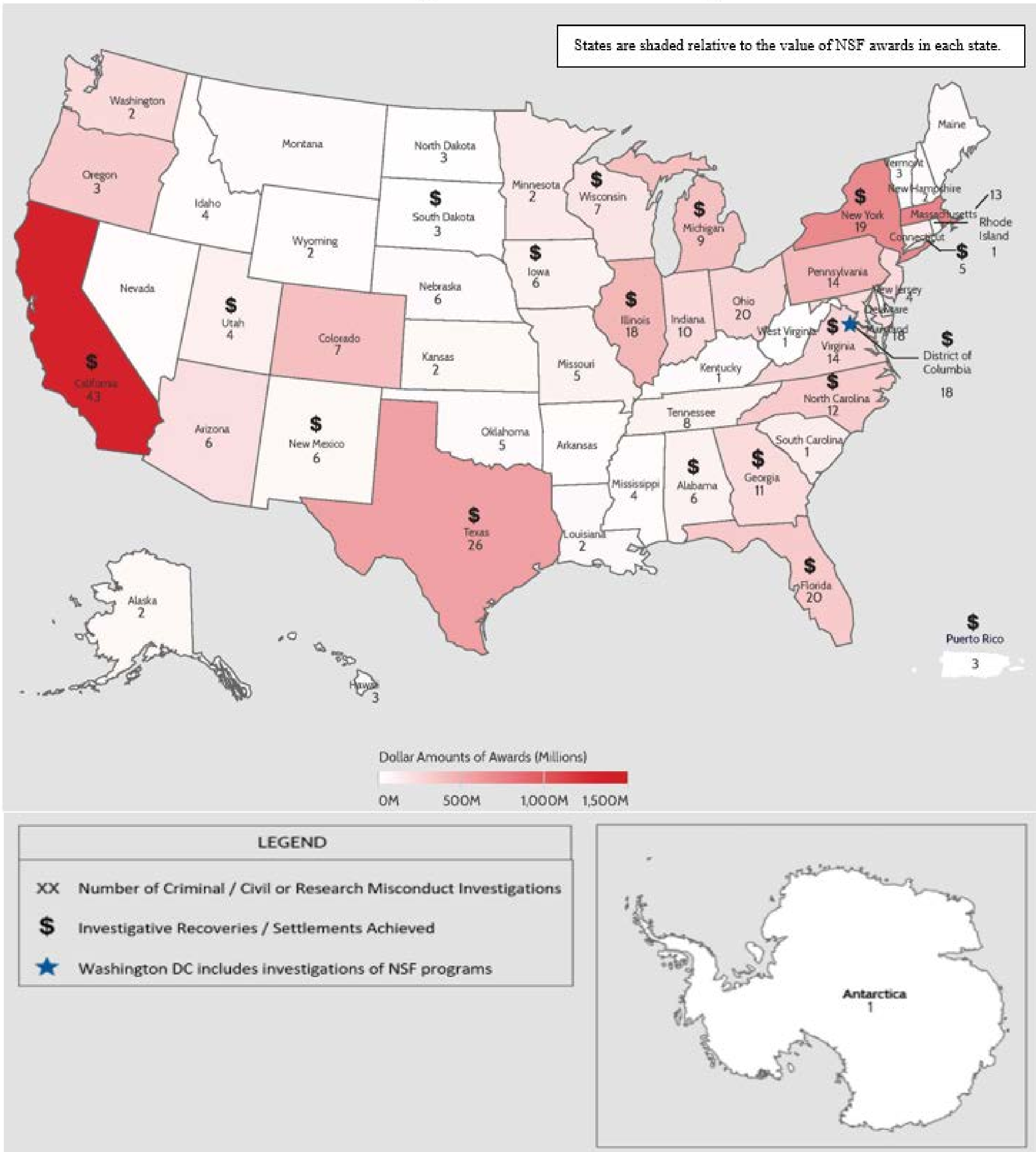
OA continuously reviews its audit approaches and techniques to identify opportunities for improvement. In FY 2018, OA reengineered its approach to internal audits by conducting audit work at awardee institutions to test the effectiveness of NSF controls. This new process will strengthen audit findings and help NSF improve its controls. OA also improved its process of contracting for grant and contract audits to ensure it has the flexibility to address the highest risk areas. In the past, contractors only conducted incurred cost audits. The new model includes an audit survey that evaluates the awardee's risks on site and recommends the optimal type of audit to address those risks. This new approach will help ensure OA can address systemic issues relating to proper management of Federal funds, recapture misused funds, and ensure proper stewardship of Federal funds going forward.

To increase efficiency and effectiveness, OA has also begun developing additional data mining tools for use in performing both internal and external audits. These new text-mining capabilities will allow the office to quickly analyze hundreds of documents, which would otherwise need to be reviewed one at a time, and combine predictive analytic capabilities to identify high-risk transactions, misuse of funds, or potentially fraudulent activity.

Investigative Impact and Strategic Focus

OIG's Office of Investigations (OI) conducts investigations of criminal, civil, and administrative wrongdoing related to NSF programs and operations, including all entities and individuals that receive NSF funds. OIG also evaluates allegations of research misconduct such as data fabrication, data falsification, and plagiarism related to NSF-funded research. As the map below illustrates, OI's investigative oversight of the NSF award portfolio is expansive. In FYs 2017-2018 OI conducted 382 investigations spanning 46 states, as well as Washington DC, Puerto Rico, and Antarctica.

NSF OIG Investigations October 2016 – August 2018



When appropriate, OI refers the results of their investigations to the Department of Justice or other authorities for criminal prosecution, civil litigation, resolution via settlement agreements and institutional compliance plans, and other administrative actions to protect federal funds. OI's investigations resulted in numerous and significant criminal convictions, civil settlements, investigative recoveries, award suspensions and terminations, and government-wide suspensions and debarments of individuals and entities.

OI investigations yield substantive results for NSF and the Federal government. Since FY 2009, OI investigations have resulted in numerous convictions and financial recoveries to the Federal government of over $65.0 million, including nearly $51.0 million of NSF funds. In FYs 2015-2018, OIG's investigations resulted in nearly $29.0 million in recoveries, or approximately $362,500 per OI line investigator, as well as 122 suspensions, debarments, or other actions taken to protect federal funds from unscrupulous individuals and entities. In FY 2019 to date, OI investigations have resulted in over $3.0 million in recoveries. OI's vigilance ensures that those who receive NSF funds to conduct research are held accountable and serves as an important deterrent to grant fraud and research misconduct.

Continuing and emerging threats to the integrity of funded research challenge OI's ability to oversee NSF's award portfolio. Foreign threats to American research and development, as well as growth in Small Business Innovation Research and Small Business Technology Transfer (SBIR /STTR) cases, continue to increase the size and complexity of OI's workload.

Beginning in FY 2018 and continuing into FY 2019, OI initiated its first criminal investigations focused on potential misuse of NSF funding by members of foreign "talent plans". Recent Congressional hearings have also focused on the theft of U.S. federally-funded research and development by foreign states who use talent plans to exploit the openness of American universities and research enterprises. OI has confronted this national security threat through close collaboration with the FBI and other investigative partners and is engaged in many efforts to assess whether actions by participants in such plans violated Federal laws, rules, or regulations. There are costs associated with these investigations that do not apply to other civil or criminal investigations because documentary evidence along with interviews conducted in a foreign language may require transcription or the services of a certified translator.

OI is also working to address fraud in the SBIR/STTR programs. Through its leadership of an OIG community working group focused on fraud in these programs, OI has generated more than 195 SBIR/STTR cases since 2010. With NSF's total annual SBIR/STTR award expenditures now approaching $200.0 million, protecting SBIR/STTR funds from fraud and abuse has become even more important. OI has successfully partnered with NSF program managers to improve SBIR/STTR processes and procedures to reduce the opportunity for fraud to occur. OI also conducts SBIR/STTR-related outreach at semiannual NSF awardee workshops, providing guidance to the small business community on how to properly handle Federal funds and the consequences of not following the rules.

OI oversight also contributes to the integrity of funded research and to the identification of unscrupulous individuals who violate the basic precepts of responsible conduct of research through commission of data fabrication, data falsification, and plagiarism. OI's investigative scientists are respected worldwide for their expertise in dealing with research integrity violations and are often asked by international and national academic/research organizations to share their expertise regarding trends in research misconduct, particularly data falsification. They provided significant input and support for the National Academy of Science's (NAS) 2017 report on Fostering Integrity in Research, which addressed rising trends in research misconduct and other violations of research norms. OIG also conducted a review of Responsible Conduct of Research programs at awardee institutions in response to a directive in the *America COMPETES Act of 2007*. In FY 2018, OI's investigative scientists began an assessment of 10 years' worth of plagiarism cases to identify trends and other information NSF and universities can use to help address the prevalence of plagiarism in the research enterprise.

Support Offices' Actions and Impacts

Office of Management. This centralized office is responsible for strategic planning/budgeting, procurement, human resources, IT services and administrative support for the entire office. Specific functional areas in Office of Management (OM) include:

- Budget and administration—responsible for all budgetary, financial and most administrative business conducted by the office, as well as coordination with NSF to provide human resources and procurement support.
- Intake operation—all complaints regarding fraud, waste, and abuse are handled by an intake coordinator, who processes over 250 allegations annually. The external OIG Hotline website has been revamped to quickly identify substantive allegations which are then reviewed by management for consideration.
- Forensic accounting and data analytics—several years ago, we added a forensic accountant skilled in data analytics to help investigators manage the large amounts of information they received through subpoenas and other means. The forensic accountant reduced the need for contract services by over 50 percent, saving $100,000 per year. Additionally, the application of data analytics to vital functions such as contractor oversight yields further management efficiencies and cost savings.
- IT services—IT support including website maintenance and posting of reports, digital forensics, and data security. The digital forensics activity has become much more critical in investigations, as most of the evidence being captured is electronic.

Office of Counsel. The Office of Counsel (OC) consists of the Counsel to the IG and two assistant counsels, one of which is part-time. It provides comprehensive legal advice and critical analysis to the IG and all OIG divisions, including legal review of externally-issued OIG work products and certain correspondence. OC handles myriad subject areas, including audit-related support, ethics, appropriations law, acquisitions, information disclosure, privacy, personnel, and IG Act authorities. OC also supports the larger IG community through active participation in CIGIE projects and committees. On average, OC handles more than 150 actions per year, which include routine reviews, Freedom of Information requests, and legal opinions on various matters.

Immediate Office. The Inspector General's immediate office includes the Chief of Staff and Executive Assistant. The Chief of Staff handles all matters relating to external affairs, primarily congressional relations, and public/media contacts.

Government-wide Impact

Though small relative to many other OIGs, NSF OIG continues to make significant contributions to the Inspector General community and the government at large. For example:

- NSF's Inspector General has served as the vice chair of the Council of the Inspectors General on Integrity and Efficiency (CIGIE) since 2014, which includes:
    1. chairing CIGIE's IG Candidate Panel to help the White House identify strong candidates for vacant Presidentially-Appointed Senate-confirmed IG positions;
    2. representing the IG community in a Five-Eyes effort focused on counter-fraud begun by the British government; and
    3. leading CIGIE's Grant Reform Working Group, which provides valuable feedback and insights to OMB staff as they consider grant-related changes.
- NSF OIG has conducted outreach to the Federal IG community, provided training to other investigative agencies, and taken the lead to establish and run four IG community working groups to:
    1. prevent fraud within the SBIR/STTR programs;
    2. increase the use of government-wide suspension and debarment as tools to deter and reduce instances of fraud, waste and abuse;
    3. foster the next generation of senior investigative leaders within the IG community; and
    4. address emerging threats to U.S. national security through efforts by foreign governments to steal intellectual property and other research.
- In FY 2017, OI hosted its fifth government-wide Suspension and Debarment 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 Attorneys' Offices. Because of these workshops, several agencies that were not previously using suspensions or debarments to protect federal funds have begun to do so, while other agencies already using them are employing them more effectively. OIG staff are working with the Interagency Suspension and Debarment Council to plan the sixth suspension and debarment workshop in FY 2019.

Financial Discussion

Office of Inspector General
Personnel Compensation and Benefits and General Operating Expenses
(Dollars in Thousands)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2020 Request	Change Over FY 2018 Actual Amount	Percent
Personnel Compensation and Benefits[1]	$12,217	-	$12,825	$608	5.0%
Travel & Transportation of Persons	250	-	300	50	20.0%
Advisory & Assistance Services[2]	1,960	-	1,840	-120	-6.1%
Rent	86	-	120	34	39.5%
Information Technology	127	-	25	-102	-80.3%
Communications, Supplies, Equipment & Other Services	447	-	240	-207	-46.3%
Training	*176*	-	*100*	*-76*	*-43.2%*
Other	*271*	-	*140*	*-131*	*-48.3%*
Total, OIG	**$15,087**	**$15,200**	**$15,350**	**$263**	**1.7%**
Full-Time Equivalents	68	71	68	-	N/A

[1] FY 2020 PC&B includes base salary costs and anticipated within grade and promotion increases.

[2] Includes the costs of the annual financial statements audit and the outsourcing of contracting services.

With an FY 2020 appropriation of $15.35 million, OIG will perform the core elements of its mission and reduce its workforce to 68 FTEs, a reduction of three staff from FY 2019. During the past five years, the average cost per FTE increased by approximately 25 percent due to a rise in benefit expense, as well as the mission essential replacement of lower wage administrative staff with auditors and investigators.

Travel costs for both audits and investigations are expected to increase by about 20 percent over current levels by FY 2020 due to several factors, including travel to the Antarctic for oversight work associated with the McMurdo modernization, as well as the expanding landscape of OIG investigations, as previously described.

For these reasons, the Budget requests an increase of $263,000 in FY 2020. In addition, to help absorb anticipated cost increases due to travel and other cost increases, OIG will reduce the number of staff as well as spending in other areas, including contracts, IT resources, and training.

MAJOR MULTI-USER RESEARCH FACILITIES

Facilities:

Federally Funded Research and Development Centers (FFRDCs):

Other Facilities:

MAJOR MULTI-USER RESEARCH FACILITIES

Major Multi-User Research Facilities Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total Research and Related Activities	**$1,082.51**	**-**	**$866.55**	**-$215.96**	**-19.9%**
Operations and Maintenance of Existing Facilities	714.73	-	605.10	-109.63	-15.3%
Federally Funded Research and Development Centers	291.94	-	240.04	-51.90	-17.8%
Operations and Maintenance of Facilities under Construction	33.10	-	17.01	-16.09	-48.6%
R&RA Design Stage Activities	42.74	-	4.40	-38.34	-89.7%
Major Research Equipment and Facilities Construction	**$185.73**	**-**	**$222.23**	**$36.50**	**19.6%**
Total, Major Multi-User Research Facilities	**$1,268.24**	**-**	**$1,088.78**	**-$179.46**	**-14.2%**

NSF investments in major multi-user research facilities (major facilities) provide large, state-of-the-art tools for research and education. These can include instrumentation networks, observatories, accelerators, telescopes, research vessels, aircraft, and simulators. In addition, scientific utilization of cyber-enabled and geographically-distributed facilities continues to increase 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 facilities are funded through the R&RA account. Most construction is funded through the MREFC account.

In FY 2018, NSF created the new position of Chief Officer for Research Facilities in the Office of the Director, to enhance oversight of major facilities throughout their complete lifecycle. The individual in that position serves as the senior agency official whose responsibility is oversight of the development, construction, and operations of major facilities across the Foundation, as required by Section 110 of the American Innovation and Competitiveness Act (P.L. 114-329).

The Facility Operation Transition activity proposed in the Integrative Activities (IA) section is a pilot program that reflects NSF's strategic commitment to successful operations and maintenance (O&M) of new major facilities as well as balancing portfolio funding between facilities and investigator research, both of which were emphasized in the NSB's Congressionally requested 2018 report entitled "Study of Operations and Maintenance Costs for NSF Facilities" (NSB-2018-17).[1] NSB envisioned a more flexible MREFC account as one way to achieve these goals; owing to the challenges that would be introduced by maintaining separate construction and operations funding in the MREFC line, the recommended strategic funding is requested in the R&RA account instead. The funds in this activity will be used to (1) partially support initial O&M of new facilities so that the full O&M costs can be gradually absorbed into the managing division or directorate, and (2) partially support divestment of lower-priority facilities, the full cost of which may significantly impact individual divison or directorate funding.

A total of $10 million is requested for the Facility Operation Transition activity. Of this amount, $8 million will support O&M for NSF facilities that are within the first five years of their operational life—the Ocean

[1] National Science Board, *Study of Operations and Maintenance Costs for NSF Facilities* (NSB-2018-17), May 2018, www.nsf.gov/pubs/2018/nsb201817/nsb201817.pdf.

Observatories Initiative (OOI), the National Ecological Observatory Network (NEON), and the Daniel K. Inouye Solar Telescope (DKIST). This funding will be divided among the three facilities in proportion to their total O&M requirements. This amount is less than 10 percent of the O&M costs of these three facilities, so that the majority of the funding remains the responsibility of the managing directorate. The Facility Operation Transition funds will assist the research directorates in sustaining the core research needed to take advantage of the new facility capabilities. The remaining $2 million for this activity will support an analysis of NSF's facilities portfolio in order to determine science priorities and divestment opportunities, as well as investments in actual divestment activities. The distribution of IA support between facilities O&M and divestment will be re-evaluated annually as new facilities come online and lower-priority facilities are removed from NSF's portfolio. This program as a whole will be reevaluated after three years to determine whether it should be modified, continued, or ended.

This chapter provides descriptions of each major facility supported through the R&RA account and provides funding information by lifecycle 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 and funded through NSF's MREFC account is provided in the MREFC chapter. The following pages contain information on NSF's major facilities in FY 2020.

MAJOR MULTI-USER RESEARCH FACILITIES FUNDING, BY PROJECT

(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Operations and Maintenance of Major Facilities	**$1,039.77**	**-**	**$861.94**	**-$177.83**	**-17.1%**
Biological Sciences	***$67.90***	**-**	***$62.60***	***-$5.30***	***-7.8%***
National Ecological Observatory Network (NEON)	67.90	-	62.60	-5.30	-7.8%
Engineering	***$22.37***	**-**	***$11.75***	***-$10.62***	***-47.5%***
Natural Hazards Engineering Research Infrastructure (NHERI)	22.37	-	11.75	-10.62	-47.5%
Geosciences	***$342.11***	**-**	***$293.40***	***-$48.71***	***-14.2%***
Academic Research Fleet[2]	86.03	-	74.10	-11.93	-13.9%
Geodesy Advancing Geosciences and EarthScope (GAGE)	12.66	-	12.64	-0.02	-0.1%
International Ocean Discovery Program (IODP)	47.55	-	45.80	-1.75	-3.7%
National Center for Atmospheric Research (NCAR) FFRDC	126.34	-	99.70	-26.64	-21.1%
Ocean Observatories Initiative (OOI)	44.08	-	38.00	-6.08	-13.8%
Seismological Facilities for the Advancement of Geoscience & EarthScope (SAGE)	25.45	-	23.16	-2.29	-9.0%
Mathematical and Physical Sciences	***$368.57***	**-**	***$295.05***	***-$73.52***	***-19.9%***
Arecibo Observatory	13.52	-	4.26	-9.26	-68.5%
Cornell High Energy Synchrotron Source (CHESS)	22.00	-	7.00	-15.00	-68.2%
Gemini Observatory	34.02	-	20.28	-13.74	-40.4%
Large Hadron Collider (LHC) - ATLAS and CMS[3]	15.86	-	20.00	4.14	26.1%
Large Synoptic Survey Telescope (LSST)	11.10	-	-	-11.10	-100.0%
Laser Interferometer Gravitational Wave Observatory (LIGO)[4]	39.43	-	44.60	5.17	13.1%
National High Magnetic Field Laboratory (NHMFL)	54.16	-	36.78	-17.38	-32.1%
National Optical Astronomy Observatory (NOAO) FFRDC	26.76	-	22.91	-3.85	-14.4%
National Radio Astronomy Observatory (NRAO) FFRDC[5]	83.01	-	85.66	2.65	3.2%
National Solar Observatory (NSO) FFRDC[6]	30.82	-	21.14	-9.68	-31.4%
National Superconducting Cyclotron Laboratory (NSCL)	24.00	-	22.00	-2.00	-8.3%
Other Astronomical Facilities FFRDC[7]	13.91	-	10.42	-3.49	-25.1%
Office of Polar Programs	***$238.82***	**-**	***$199.14***	***-$39.68***	***-16.6%***
Antarctic Facilities and Operations[8]	231.82	-	192.14	-39.68	-17.1%
IceCube Neutrino Observatory	7.00	-	7.00	-0.00	-0.00
Major Research Facilities Construction Investments	**$228.47**	**-**	**$226.63**	**-$1.84**	**-0.8%**
R&RA Design Stage Activities[9]	**$42.74**	**-**	**$4.40**	**-$38.34**	**-89.7%**
Major Research Equipment and Facilities Construction (MREFC)	**$185.73**	**-**	**$222.23**	**$36.50**	**19.6%**
Total, Major Multi-User Research Facilities	**$1,268.24**	**-**	**$1,088.57**	**-$179.67**	**-14.2%**

FFRDC is an acronym for Federally-Funded Research and Development Center.

[1] In FY 2018 Congress appropriated additional one-time funding to NSF above the Request level, which was in part allocated to numerous major facilities. These include: NEON, NHERI, Academic Research Fleet, NCAR, Antarctic Facilities & Operations, CHESS, Gemini, LHC, LIGO, NHMFL, NOAO, NRAO, and NSO. In addition, Arecibo Observatory and NRAO received supplemental appropriations (PL 115-123) in the amount of $16.30 million. For more information, please refer to the individual narratives in the Facilities chapter.

[2] Includes ship operations and upgrade support. ALVIN operations and upgrade is also included here. For more information on which vessels are considered major facilities, please refer to the Academic Fleet narrative. Regional Class Research Vessels (RCRV) began construction in FY 2017 and is included in the MREFC line below.

[3] Excludes $16.60 million in FY 2018 for planning for a potential High-Lumosity LHC upgrade. That funding is captured on the R&RA Design Stage Activities line below.

[4] Excludes $10.0 million in FY 2018 and $400,000 in FY 2020 for LIGO A+. That funding is captured on the R&RA Design Stage Activities line below.

[5] Includes operations and maintenance support for the Atacama Large Millimeter Array of $38.55 million in FY 2018 and $47.26 million in FY 2020. FY 2020 includes $3.43 million for the reintegration of the Long Baseline Observatiory (LBO). Also included is early developmental funding for the potential next generation Very Large Array (ngVLA) of $6.0 million in FY 2018.

[6] Includes $22.0 million in FY 2018 and $17.01 in FY 2020 for operations and maintenance support for the Daniel K. Inouye Solar Telescope (DKIST) facility construction project.

[7] Includes funding in FY 2018 for the Green Bank Observatory (GBO) and the Long Baseline Observatory (LBO). FY 2020 funding includes support for GBO only as LBO funding is reintegrated into NRAO beginning in FY 2019. $2.0 million is included in each year for cultural mitigation activities as agreed to during the environmental compliance process for DKIST.

[8] Excludes $16.14 million in FY 2018 for planning AIMS. That funding is captured on the R&RA Design Stage Activities line below.

[9] Design Stage Activities include support for potential next generation multi-user facilities. This line reflects funding for AIMS in FY 2018 ($16.14 million); for a potential HL-LHC in FY 2018 ($16.60 million, of which $7.50 million funds FY 2019 and FY 2020 activities); for LIGO A+ ($10.0 million in FY 2018 and $400,000 in FY 2020); and for the potential Leadership Class Computing Facility in FY 2020 ($4.0 million).

ACADEMIC RESEARCH FLEET (ARF) **$74,100,000**
-$11,930,000 / -13.9%

Academic Research Fleet Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$86.03	-	$74.10	-$11.93	-13.9%

[1] FY 2018 Actual includes $6.0 million in additional FY 2018 one-time funding above the requested amount.

The U.S. Academic Research Fleet included 18 vessels in calendar year 2018 with the two new Office of Naval Research (ONR) vessels (R/V *Neil Armstrong* and R/V *Sally Ride*) being fully integrated 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 the ARF includes investments in ship operations; shipboard scientific support equipment; oceanographic instrumentation and technical services; and submersible support. Funding levels reported here reflect investments by the Division of Ocean Sciences (OCE) within GEO. 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. Details on these construction activities are contained in the Fleet Modernization section.

Total Obligations for ARF
(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[2] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$80.03	-	$74.10	$74.10	$74.10	$74.10	$74.10	$74.10
Facility Upgrade								
Alvin upgrade	6.00	-	-	-	-	-	-	-
Total	**$86.03**	**-**	**$74.10**	**$74.10**	**$74.10**	**$74.10**	**$74.10**	**$74.10**

[1] FY 2018 Actual includes $6.0 million in additional FY 2018 one-time funding above the requested amount.
[2] Outyear estimates are for planning purposes only.

Facility Upgrade: In FY 2018, NSF awarded $6.0 million provided above the Requested level for upgrades to Deep Submergence Vehicle (DSV) Alvin. For more information on the upgrade please see Fleet Modernization section below.

The ARF serves as the main platform for the collection of data and testing of hypotheses about the structure and dynamics of the ocean, as well as 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.

The ARF is financially supported through an interagency partnership, principally with the Office of Naval

[1] www.nopp.org/wp-content/uploads/2010/03/federal_oceanographic_fleet_status_report.pdf

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 over the past several years, including 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.

Funding for scientists using the fleet is provided by NSF and other federal and state agencies. Within NSF, science is funded through competitive peer-reviewed proposals, most typically funded within OCE and through selected programs in the Division of Earth Sciences, Division of Atmospheric and Geospace Sciences, OPP, and 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 ARF, and science funded by other agencies.

The FY 2020 funding level of $74.10 million will support approximately 1,625 ship operating days, and includes the entry into the fleet of the R/V *Rachel Carson* (owned by the University of Washington) replacing the retired NSF-owned R/V *Clifford A. Barnes*. During FY 2020 the ONR-owned Global Class R/V *Revelle* will re-enter the fleet after a one-year mid-life refit and the ONR-owned Global Class R/V *Atlantis* will enter her mid-life refit period which will have a one-year duration. In addition to being a general purpose research vessel, R/V *Atlantis* also serves as the support ship for the Deep Submergence Vehicle (DSV) Alvin. Alvin is scheduled to undergo a major refit during the same period R/V *Atlantis* will be out of service. Additional details are included in the Fleet Modernization section below.

Fleet Operations/Management and Oversight

- Oversight: NSF provides oversight to the ARF 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 the ARF, regardless of owner. In addition, NSF oversees the fleet through Business Systems Reviews, site visits, ship inspections, 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 ARF. For purposes of performing proper oversight under AICA, seven individual vessels out of the eighteen in the ARF have been designated as major facilities. Additionally, once they reach the operations stage, the three RCRVs will be included in this group as well.
- After an in-depth review of the application of rate structures on ARF ship-related activities, NSF and ONR have transitioned 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 *Final Recommendations of the Interagency Ocean Policy Task Force*[2] 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*[3]

[2] https://obamawhitehouse.archives.gov/files/documents/OPTF_FinalRecs.pdf
[3] www.nap.edu/catalog/12775/science-at-sea-meeting-future-oceanographic-goals-with-a-robust

published in 2009, and *Critical Infrastructure for Ocean Research and Societal Needs in 2030*[4] 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*[5] 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 2016.[6] In January 2015, the National Academy of Sciences Report *Sea Change 2015-2025 Decadal Survey of Ocean Sciences*[7] identified the U.S. Academic Research Fleet as having "the strongest match between current infrastructure and the decadal science priorities" and emphasized the overall importance of ships in all of the 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.

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.
- Ocean Class Research Vessels: ONR funded the design and construction of two new Ocean Class Research Vessels which have now been fully integrated into the ARF operating schedule. R/V *Neil Armstrong* operated by the Woods Hole Oceanographic Institution replaced the Global Class R/V *Knorr* and R/V *Sally Ride* operated by Scripps Institution of Oceanography replaced Global Class R/V *Melville.*
- Regional Class Research Vessels (RCRV): In March 2012, NSF leadership approved the request to advance the RCRV to the Conceptual Design Review (CDR) phase as a candidate MREFC project. Funds to initiate construction were requested and appropriated in FY 2017. Keel-laying for the first RCRV named R/V *Taani* was completed in November 2018. The RCRV will address requirements across government agencies for research vessels in support of ocean science research as discussed in the Fleet Status Report Update of 2016. Keel laying for the second RCRV named R/V *Resolution* will be in May 2019. 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. Delivery of R/V *Sikuliaq* 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. R/V *Sikuliaq* successfully completed ice trials in the Bering Sea and three science cruises in the Arctic Ocean during 2015. All final MREFC project activities were closed out under budget by March 2016. R/V *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. R/V *Sikuliaq* greatly expands research and technology capabilities in the Arctic, providing up to 250-300 science days at sea annually.
- DSV Alvin: The Alvin upgrade project consists of two phases:
    - Phase One, completed in 2014, consisted of a major overhaul of all vehicle systems and incorporation of a new titanium personnel sphere, which resulted in continued operation of the submersible at its historic depth rating of 4500 meters.
    - Phase Two, funded in 2018, with $6.0 million, will enable operations to 6500 meters water depth and thus expand the accessible area of operations for Alvin from approximately 60 percent of the

[4] www.nap.edu/catalog/13081/critical-infrastructure-for-ocean-research-and-societal-needs-in-2030
[5] www.nopp.org/wp-content/uploads/2010/03/federal_oceanographic_fleet_status_report.pdf
[6] www.nopp.org/wp-content/uploads/2016/06/federal_fleet_status_report_final_03.2016.pdf
[7] www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences

seafloor to more than 95 percent. It will also enable relatively shallow, mid-water work in places where the water depth currently prohibits operations. The Alvin Upgrade Project Team at Woods Hole Oceanographic Institution is working with the Naval Sea Systems Command to design, fabricate, test, and certify all components necessary to complete the upgrade. The primary long-lead item remaining in the schedule is the variable ballast system, which will require design, fabrication, testing and certification of new pressure spheres. This system, as well as new foam floatation and other improvements, will be ready for incorporation into Alvin during the overhaul in 2020, concurrent with the mid-life refit of the support ship R/V *Atlantis*.

Renewal/Recompetition/Termination

Ships supported by NSF are operated by academic institutions, each having a cooperative agreement with NSF. Renewal of all ship cooperative agreements, with the exception of one vessel, were renewed in FY 2018 using a process including external panel review. All future cooperative agreements for ship operator awards for NSF-owned ships will undergo an open competition every ten years. Awardees are subject to additional oversight measures, including quarterly safety and financial reporting, the use of NSF Business System Reviews, and site visit inspections. In 2018, NSF retired R/V *Clifford A. Barnes*, operated by the University of Washington, which was replaced by the R/V *Rachel Carson* purchased by the University of Washington.

ANTARCTIC FACILITIES AND OPERATIONS

$192,140,000
-$55,820,000 / -22.5%

Antarctic Facilities and Operations Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$247.96	-	$192.14	-$55.82	-22.5%

[1] FY 2018 Actual includes $42.58 million in additional FY 2018 one-time funding above the requested amount.

Antarctic Facilities

OPP 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, 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. 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, 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 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).

Total Obligations for Antarctic Facilities
(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES[2]				
	Actual[1]	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Antarctic Facilities and Operations	$203.24	-	$192.14	$192.14	$192.14	$192.14	$192.14	$192.14
AIMS Development and Design	16.14	-	-	-	-	-	-	-
Palmer Pier Upgrade	28.58	-	-	-	-	-	-	-
Total	**$247.96**	**-**	**$192.14**	**$192.14**	**$192.14**	**$192.14**	**$192.14**	**$192.14**

[1] FY 2018 Actual includes $42.58 million in additional FY 2018 one-time funding above the requested amount; $14.0 million for AIMS Development and Design and $28.58 million for Palmer Pier constuction.

[2] Outyear estimates are for planning purposes only.

The FY 2020 Budget Request for Antarctic Facilities is $192.14 million. The reduction relative to FY 2018 is primarily due to one-time investments made in FY 2018 to replace the aging pier at Palmer Station, funding to advance Antarctic Infrastructure Modernization for Science (AIMS) development and design and other miscellaneous improvements. In FY 2020, funds will provide for station operations and science support at NSF's three Antarctic stations, various near and deep field camps, and two leased research vessels.

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 *Polar Star* returned to service in 2014 and provides annual icebreaking services for the McMurdo Station resupply effort.

Management and Oversight

- NSF Structure: OPP staff, including subject matter experts in operational and scientific disciplines, have overall responsibility for managing Antarctic Facilities under the U.S. Antarctic Program (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 and Logistics section enables research in Antarctica on behalf of the U.S. government through a network of stations, labs, equipment, and logistical resources.

Helicopters provide support to field parties in the McMurdo Dry Valleys in southern Victoria Land and at remote field camps. *Credit: Kristan Hutchison, RPSC.*

- 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 BFA. In addition, OPP's performance is reviewed externally by Committees of Visitors and the OPP Advisory Committee. The USAP Blue Ribbon Panel (BRP) released a report on its review of the program in July 2012.[1] The initial NSF response to the USAP BRP report was released in March 2013 and progress to address recommendations is ongoing.[2] This budget request includes a request for funding for the AIMS project, a major part of the NSF response to the BRP report.

<u>Current Status</u>

- 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.
    - For example, construction is underway to upgrade satellite communications systems to support operations and research, and construction activities to replace the Palmer Station pier to ensure long-term access to unique research in the peninsula region could begin as early as the 2020 austral summer season. NSF is also constructing a consolidated Information Technology and Communications building. This was phased to ensure continuous functionality when the AIMS project construction gets underway in FY 2020.

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[1] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp
[2] www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/nsf_brp_response.pdf

- The National Science Board authorized NSF to award the AIMS project. Leidos is in the process of completing the designs of all construction components, beginning the site preparation work for the backbone utilities and the initial buildings such as the Vehicle and Equipment Operations Center, and procuring the first phases of construction equipment and materials. The AIMS project will redevelop McMurdo Station to be a consolidated, cost-effective facility, including modernized utilities distribution and fire protection. For additional information on AIMS see the AIMS narrative in the MREFC Chapter.

Renewal/Recompetition/Termination

- In FY 2012, Lockheed Martin Corporation was awarded a 13.5 year contract, consisting of a five-year base period and four option periods, exercised on the basis of performance, that total an additional eight and a half years. Leidos Innovations Corporation now holds the contract as it acquired the responsible division of Lockheed Martin in 2016.
- 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, currently held by PHI, Inc. of Lafayette, Louisiana, is currently under competition. A five-year contract for fixed-wing aviation services was recently awarded to Kenn Borek Air of Calgary, Canada.
- 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.

ARECIBO OBSERVATORY (ARECIBO)

$4,260,000
-$9,260,000 / -68.5%

Arecibo Observatory Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$13.52	-	$4.26	-$9.26	-68.5%

[1] The FY 2018 Actual includes $1.28 million in additional FY 2018 one-time funding above the requested amount, $2.0 million in supplemental appropriation funding for hurricane repairs, plus $2.69 million for forward funding of FY 2019 operations.

Arecibo is a center for multidisciplinary research and education with advanced 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 approximately 140 acres of U.S. Government-owned land. Arecibo is currently operated and managed by the University of Central Florida (UCF) and subrecipients, Yang Enterprises, Inc. (YEI) and Universidad Metropolitana (UMET), under a cooperative agreement with NSF that began on April 1, 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 about 104 full-time equivalent (FTE) employees, of which about 70 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 16 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.

Along with the entire island of Puerto Rico, Arecibo Observatory was severely impacted by Hurricane Maria, which struck on September 20, 2017. Damages to the facility included the physical infrastructure and scientific equipment. Two generators suffered damage and the other two were overused until commercial power was restored more than two months later. Basic science operations (planetary radar and radio astronomy) restarted within weeks of the storm, although at reduced and degraded performance levels. Funding for observatory repairs was provided in the Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) totaling $16.30 million. Of the total amount provided, $14.30 million was identified for Arecibo of which $2.0 million was disbursed in FY 2018 for the most critical immediate concerns including debris cleanup, rewinding of generators, repairs to damaged building infrastructure, engineering analyses, and repairs to the damaged catwalk leading to the 305-m telescope platform. An award for the remaining $12.30 million for more complex repairs, such as to the broken 430 MHz line feed and damage to the supporting steel cables which could impact overall structural integrity, will be made in FY 2019. The remaining repairs will take up to four years, carefully planned to prioritize the most critical structural repairs and to minimize impact to ongoing regular scientific observations.

Total Obligations for Arecibo
(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[2] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance (MPS)	$5.52	-	$2.13	$1.50	$1.13	$1.00	$1.00	$1.00
Operations & Maintenance (GEO)	4.71	-	2.13	1.50	1.13	1.00	1.00	1.00
Hurricane-related Repairs[3]	2.00	-	-	-	-	-	-	-
One-time FY 2018 Costs[4]	1.28	-	-	-	-	-	-	-
Total	**$13.52**	**-**	**$4.26**	**$3.00**	**$2.25**	**$2.00**	**$2.00**	**$2.00**

[1] The FY 2018 Actual includes $1.80 million in MPS and $890,000 in GEO for forward funding of FY 2019 operations.

[2] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2023.

[3] Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) provided NSF $16.30 million in no-year funding to repair radio observatory facilities damaged by hurricanes that occurred during 2017. Of the total amount provided, $14.30 million was identified for Arecibo and $2.0 million was obligated in FY 2018. The remaining $12.30 million will be obligated in FY 2019.

[4] FY 2018 one-time costs are associated with the change in management organization.

Arecibo is jointly supported by the MPS Division of Astronomical Sciences (AST) and the GEO Division of Atmospheric and Geospace Sciences (AGS). Based on the 2006 AST Senior Review recommendations,[1] AST and AGS reduced support for the Arecibo Observatory. An external review of the AST portfolio was completed in 2012, and an external review of the AGS portfolio was completed in 2016.

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."[2] The National Academies of Sciences, Engineering, and Medicine's (the National Academies) August 2016 report, *New Worlds, New Horizons: A Midterm Assessment*, reinforced this, with Recommendation 3.1 noting: "The NSF should proceed with divestment from ground-based facilities that have a lower scientific impact."[3]

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.[4] 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[5] 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 Academies that assessed the process by which the GS Portfolio Review Committee reached its findings and recommendations. The panel published the results of this review[6] in early 2017 and, for Arecibo, reiterated the recommendations of the GS Portfolio Review Committee.

[1] www.nsf.gov/mps/ast/seniorreview/sr_report_mpsac_updated_12-1-06.pdf
[2] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[3] www.nap.edu/catalog/23560/new-worlds-new-horizons-a-midterm-assessment
[4] www.nap.edu/catalog/13060/solar-and-space-physics-a-science-for-a-technological-society
[5] www.nsf.gov/geo/adgeo/geospace-review/geospace-portfolio-review-final-rpt-2016.pdf
[6] www.nap.edu/catalog/24666/assessment-of-the-national-science-foundations-2015-geospace-portfolio-review

Because of these potential changes, NSF prepared an Environmental Impact Statement (EIS) to evaluate proposed operational changes at Arecibo due to funding constraints, pursuant to the National Environmental Policy Act. NSF also completed its compliance obligations with the National Historic Preservation Act, and the Endangered Species Act. NSF prepared a Final EIS, which was published in August 2017.[7] Following publication of the EIS, NSF published a Record of Decision[8] in November 2017, which formalizes the selection of NSF's preferred alternative: to collaborate with interested parties to maintain science-focused operations at the Observatory with reduced agency funding.

NSF issued a solicitation in January 2017 requesting proposals to provide continued operations and management of Arecibo for five years at reduced funding. The planned NSF funding profile presented in the solicitation gradually tapered NSF support to $2.0 million by the fifth year of the award. In February 2018, NSF announced an award to University of Central Florida (UCF) to undertake formal transition activities for operations and management responsibilities for Arecibo Observatory in cooperative agreement with NSF. The award continues science-focused operations that will maintain the Observatory's existing research lines of atmospheric, planetary and astronomical research and continue its education and public outreach efforts.

Partnerships and Other Funding Sources: Arecibo supplements NSF support with funding provided by other federal and non-federal sources. Since FY 2010, the NASA Near Earth Object Observation Program has committed $2.0 million annually to Arecibo for the planetary radar program; this increased to $3.60 million for FY 2013, with more observing time allocated to the NASA program. In FY 2020 NASA support is expected to be approximately $4.65 million.

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. 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. There was a downturn in visitors immediately following the 2017 hurricanes, but as the island recovered the number of visitors began to return to the expected rates each month. 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 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. The 96-foot line feed hanging to the left of the Gregorian dome was broken off during Hurricane Maria into several pieces, also damaging the dish below. Repairs are underway. *Credit: Arecibo Observatory/NSF.*

[7] www.nsf.gov/mps/ast/env_impact_reviews/arecibo/arecibo_feis.jsp
[8] www.nsf.gov/mps/ast/env_impact_reviews/arecibo/arecibo_rod.jsp

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 allocated based on the quality of 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

- Funding: 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. AGS funding will support basic operations costs and science programs in aeronomy and space physics, including space weather.
- NSF Structure: The lead NSF program officer in AST, in close cooperation with a program officer in AGS and in consultation with community representatives, provides ongoing oversight. The program officers make use of detailed annual program plans, long-range plans, quarterly technical and financial reports, and annual reports submitted by the management and operations awardee. They also attend awardee governance committee meetings, as appropriate. To address issues as they arise, program officers work closely with other NSF offices such as the Office of the General Counsel and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight. AST and AGS program officers conduct periodic site visits and frequent, regular, teleconferences.
- External Structure: Management is via a cooperative agreement. In February 2018 NSF announced an award to UCF to undertake formal transition activities leading to UCF assumption of full operations and management responsibilities for Arecibo Observatory. The transition to UCF's management occurred on April 1, 2018. UCF has two sub-awardees: Yang Enterprises, Inc. (YEI) for engineering staff and facilities management and the Universidad Metropolitana (UMET) for management of the visitor's center and the education and public outreach efforts.
- Reviews: In January 2017, NSF issued a solicitation requesting proposals to provide continued operations and management of Arecibo for five years, but at reduced funding. Proposals received in response to this solicitation were afforded extensive NSF internal review together with formal review by a panel of external experts in observatory management and operations. Additionally, AST and AGS jointly conduct annual external reviews of Arecibo program plans; the most recent such review was held in January 2017. The next formal annual external review of UCF's management is scheduled to take place in the Fall of 2019.

Renewal/Recompetition/Termination

In January 2017 NSF issued a solicitation for continued operations and management of Arecibo Observatory. Following a thorough review process, in February 2018, NSF announced an award to UCF to undertake formal transition activities expected to lead to UCF assuming full operations and management responsibilities. The current cooperative agreement with UCF for the management of Arecibo was awarded in April 2018, when UCF succeeded the previous managing organization. This followed a competitive process for a new five-year cooperative agreement, consistent with NSB policy. This agreement is in effect through March 2023.

CORNELL HIGH ENERGY SYNCHROTRON SOURCE (CHESS) **$7,000,000**
-$15,000,000 / -68.2%

Cornell High Energy Synchrotron Source Funding

(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request[2]	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$22.00	-	$7.00	-$15.00	-68.2%

[1] FY 2018 Actual includes $10.0 million to fund part of FY 2019 costs.

[2] The FY 2020 Request reflects the transition of CHESS from an NSF stewardship to a partnership model in the FY 2018-FY 2019

CHESS is a high-intensity, high-energy X-ray facility located on the campus of Cornell University in Ithaca, New York. 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. This multi-user facility provides X-ray beams for 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. Oversight of the facility is provided through the MPS Division of Materials Research (DMR).

As a national user facility, CHESS provides access to beamtime through a competitive proposal review process. The primary function of the staff is to maintain and operate the facility and to assist users from across the United States and overseas. Approximately 1,200 users annually perform a broad array of research including computationally-enabled scattering studies of complex materials, along with analyses of the structure of designer solids and the impact of processing. Scientists use time-resolved synchrotron radiation to enable research in engineering of materials, X-ray imaging and spectroscopy, structural materials under operating conditions, and, in collaboration with the National Institutes of Health (NIH), the analysis of macromolecules and biochemistry. An annual meeting of users and several workshops help disseminate results from the facility.

CHESS supports users from academia, industry, and national laboratories. The facility 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. Key collaborations include work with Department of Energy (DOE)-supported synchrotron facilities, such as the Advanced Photon Source (APS), the National Synchrotron Light Source, and the Linac Coherent Light Source (LCLS) at Stanford. X-ray detectors developed at CHESS are now in use at third and fourth generation X-ray sources around the world, including LCLS, the world's first hard X-ray laser. Cornell University has just completed an upgrade to CHESS's light source, the Cornell Electron Storage Ring (CESR). CESR is now a third-generation light source of the same class as the APS. The upgrade, funded by the State of New York, incorporated cost-effective undulators developed at CHESS. These undulators will increase X-ray flux by orders of magnitude and enable scientists to pursue time-resolved and high-resolution experiments and imaging not previously possible. The CHESS-developed undulators, and other innovations such as high-flux X-ray optics, are impacting synchrotron science worldwide.

Researchers at CHESS also developed a new Kolsky bar apparatus to study the impact of high strain rates on structure using *in situ* diffraction from metals undergoing shock-wave induced strain. This unique capability uses the high flux 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, K-12 students and science teachers. The 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 to students who have used the facility for their research. CHESS is a key training ground for X-ray and accelerator scientists, with CHESS graduates being hired by other X-ray facilities in the United States and around the world.

With the recent upgrade to CESR, CHESS is now equipped with a high-energy hard X-ray synchrotron source. In FY 2017, NSF conducted a review of the science case for this upgraded X-ray facility, named CHESS-U, and determined that this upgrade would provide new capability in a niche area at CHESS, but the unique aspects lacked sufficient breadth to justify continued stewardship of the source by NSF. This led to NSF's decision to continue funding CHESS operations only through March 2019 and to accept a transition proposal in FY 2018. CHESS has proposed to establish a new partnership model, whereby NSF would consider targeted support for the most promising science and unique experimental components but no longer support full operation of the source. The initial expiration date of the cooperative agreement was March 2019. NSF has extended the award to August 2019 to allow NSF to complete the transition process. FY 2019 funding for CHESS during this transition includes $15.0 million through August 2019, $10.0 million of which was funded in FY 2018.

Total Obligations for CHESS

(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES[2]				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance (MPS)[1]	$14.00	-	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
Operations & Maintenance (BIO)	4.00	-	1.00	-	-	-	-	-
Operations & Maintenance (ENG)	4.00	-	1.00	-	-	-	-	-
Total	**$22.00**	-	**$7.00**	**$5.00**	**$5.00**	**$5.00**	**$5.00**	**$5.00**

[1] The FY 2018 MPS Actual includes $10.0 million to fund part of FY 2019 costs.

[2] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in August 2019. The process for transition of CHESS from an NSF stewardship to a partnership model began in FY 2018 and should be completed in FY 2019. Future funding is dependent on proposal review.

Management and Oversight

- NSF Structure: CHESS is supported by MPS through a cooperative agreement with Cornell University. A MPS/DMR program director is the primary contact with the facility. 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 MPS, ENG, BIO, and NIH program directors. The NSF Division of Acquisition and Cooperative Support (DACS) and the Large Facilities Office (LFO) in BFA provide oversight of financial and administrative aspects of the award. The MPS Facilities team, together with the Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight.
- 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 an internal executive committee and diversity committee as well as from external groups including the External Advisory 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 development of the facility. Annual reviews also assess the status of education, training and outreach; operations and management efficiency; and diversity plans. The reviews are conducted by a panel of experts from the research community. Representatives from NIH attend the reviews as observers. In addition to these annual scientific reviews, business reviews are conducted regularly by LFO and DACS.

Renewal/Recompetition/Termination

With the awarded five-month extension, the new expiration date of the current cooperative agreement is August 2019. Pending the outcome of the proposal to transition to a partnership role, a new award is expected to be in place no later than September 2019. This partnership, which NSF will monitor closely, will be for a period of five years. Support thereafter will depend on successful operation in the partnership mode and meritorious review of a renewal proposal.

GEMINI OBSERVATORY (GEMINI) $20,280,000
-$13,740,000 / -40.4%

Gemini Observatory Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$34.02	-	$20.28	-$13.74	-40.4%

[1] FY 2018 Actual includes $13.0 million in additional FY 2018 one-time funding above the requested amount.

The Gemini Observatory consists of twin optical/infrared eight-meter telescopes, one each in the northern and southern hemispheres, thereby providing complete coverage of the sky. Gemini North sits atop Maunakea, Hawai'i at an elevation of 4,200 meters, while Gemini South is located on the 2,700-meter summit of Cerro Pachón, Chile. Both telescopes offer a suite of modern optical and infrared instrumentation and employ sophisticated adaptive optics technology to compensate for the blurring effects of the Earth's atmosphere.

Among the fundamental questions being investigated at Gemini are those pertaining to 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 birth of stars and their planetary systems. Technological advances incorporated into the design of the two telescopes optimize their imaging capabilities and infrared performance as well as their ability to quickly swap instruments in response to changing atmospheric conditions. Gemini's flexible observing modes make it ideal for reacting rapidly to opportunities that arise in the new era of multi-messenger astronomy. Gemini is also developing software and hardware aimed at enhancing its ability to respond to the expected growth in demand for observations needed to characterize objects discovered by NSF facilities like the Large Synoptic Survey Telescope (LSST), the Laser Interferometer Gravitational-Wave Observatory (LIGO), and the IceCube Neutrino Observatory.

The research agencies that currently form the Gemini international partnership include: NSF; the National Research Council of Canada; the Ministério da Ciência, Tecnologia e Inovação of Brazil; the Ministerio de Ciencia, Tecnología e Innovación Productiva of Argentina; the Comisión Nacional de Investigación Científica y Tecnológica of Chile; and the Korea Astronomy and Space Science Institute of South Korea, which joined the partnership in July 2018. These six agencies are signatories to the Gemini International Agreement, which currently covers January 2016 through December 2021. Renewal of this agreement beyond 2021 is currently under negotiation, with all participants expressing their intentions to remain in the partnership.

Gemini helps educate astronomy and engineering students through undergraduate internship programs in both Hawai'i 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, Hawai'i (now in its 15th year) and its sister activity, *Viaje al Universo* in La Serena, Chile, bring astronomy into the classroom through week-long annual events that involve dozens of astronomers from Gemini as well as from many of the other astronomical facilities at each location. Gemini staff 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.

The observatory supports four facility-class instruments at each telescope as well as a vigorous visiting instrument program. Each telescope is equipped with adaptive optics and laser guide star systems which greatly improve the ability to correct for atmospheric blurring. The unique Multi-Conjugate Adaptive Optics (MCAO) system on Gemini South provides near-infrared images that are often sharper than those observed from space, covering a field-of-view on the sky that is wider than any competing system on the ground. With support from NSF, the observatory is developing a similar capability for Gemini North. Together, these two MCAO systems will provide the Gemini community with this unique capability over both hemispheres.

The Gemini South telescope in Chile firing its laser into the night sky (left). The laser produces a “constellation” of five synthetic guide stars (center) that are used to correct for atmospheric blurring. The Gemini observation (on the right) of a Globular Cluster shows an example of an image sharpened in this way. *Credit: Gemini Observatory/NSF/AURA.*

The observatory is developing a number of new imagers and spectrometers. Instrument development is funded by the partners as a portion (typically 10 percent) of their annual operations contributions. These instrumentation funds are currently being used to build the Gemini High-resolution Optical SpecTrograph (GHOST), a workhorse instrument for studying a vast array of astronomical objects, and an eight-beam optical/infrared spectrograph known as SCORPIO. SCORPIO will be used to characterize exotic transient phenomena discovered with LSST, LIGO, and other time-domain facilities in the 2020s. Two other major instruments are being designed and built by Gemini partners: the Gemini InfraRed Multi-Object Spectrograph, GIRMOS (Canada), and a successor to a hugely popular visiting instrument, the Immersion GRating INfrared Spectrograph, IGRINS (South Korea and the United States). Together these four instruments will greatly enhance Gemini’s capabilities well into the next decade, ensuring the observatory stays at the forefront of astronomical research in all areas.

Construction of the telescopes and their instrumentation involved a large number of industrial entities in several countries, with areas of specialization that included large and complex optical systems, engineering, electronics, electro-mechanical systems, and computing. Continued development in these 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 from any researcher in the U.S. astronomical community, with peer-review committees providing merit-based telescope time. NSF does not provide awards targeted specifically for the use of Gemini, although U.S. users are often supported through separate NSF research awards to pursue scientific programs that require the use of the observatory. In a typical year, approximately 600 unique observing programs are submitted to Gemini, 70 percent of which are from U.S.-based astronomers.

In the FY 2020 Budget Request, NSF plans to maintain full operations of Gemini Observatory through the entire fiscal year. The Budget Request of $20.28 million includes the full contribution of the NSF (U.S.) share of facility operations costs. Due to recently provided funding for facility upgrades, the requested budget does not include any NSF (U.S.) contribution to the Gemini Instrument Development Fund (IDF), which is obtained through partner contributions that typically have been 10.0 percent of annual operations contributions in recent years.

Total Obligations for Gemini

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$21.02	-	$20.28	$22.98	$23.67	$23.67	$23.67	$23.67
Facility Upgrades[2]	13.00	-	-	-	-	-	-	-
Total	**$34.02**	**-**	**$20.28**	**$22.98**	**$23.67**	**$23.67**	**$23.67**	**$23.67**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends December 2022.

[2] FY 2018 Actual includes $13.0 million in additional FY 2018 one-time funding above the requested

Facility Upgrades: In FY 2018, NSF awarded $13.0 million for support of three related projects: (1) the development of a state-of-the-art MCAO system for Gemini North, (2) software improvements needed to optimize Gemini's capability for rapid time-domain follow-up of transient sources and alerts for multi-messenger astronomy (MMA), and (3) public information and outreach activities focused on MMA.

Management and Oversight

- Governance Structure: The observatory is governed by the Gemini Board, which was established by the Gemini International Agreement signed by the six participating agencies mentioned above. This board meets at least twice a year and acts as the primary forum for interactions and decisions among the participants in the Gemini Agreement; the Gemini Board ensures that Gemini is managed and operated in accordance with the Agreement and is the body with overall budgetary and policy control over the observatory. The Gemini Board is supported by two sub-committees, the Gemini Finance Committee (GFC) and the Gemini Science and Technology Advisory Committee (STAC). NSF serves as the Executive Agency for the partnership, carrying out the project on their behalf. The United States holds six of the 14 seats on the Gemini Board; NSF appoints the five non-NSF U.S. members.
- Managing Organization: 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. The current cooperative agreement covers January 2017 to December 2022. AURA conducts its own management reviews through oversight committees.
- NSF Structure: NSF has one seat on the Gemini Board, currently occupied by the AST program officer responsible for Gemini programmatic oversight. Another NSF staff member serves as Board executive secretary. 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 Board sponsored sub-committees, and approves funding actions, reports, and contracts. The program officer is also currently the chair of the GFC. To address issues as they arise, AST has a dedicated Integrated Project Team (IPT) which includes representatives from other NSF offices, such as the Office of General Counsel, OISE, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight.
- Reviews: In addition to the oversight activities of the Gemini Board and its subcommittees, NSF conducts periodic reviews of the management and operation of the observatory, and of AURA's

financial systems. The IPT reviews quarterly operations, development, and financial plans, and also the observatory's annual progress report and program operations and development plan for the coming year. NSF conducted a Business System Review (BSR) of the observatory and AURA's centralized administrative services in 2013. In April 2017, NSF conducted a Gemini Accounting System Audit, and plans to conduct an Incurred Cost Audit of the Gemini cooperative agreement and a new BSR in 2019 or early 2020.

Renewal/Recompetition/Termination

The United Kingdom withdrew from the Gemini partnership at the end of 2012, resulting in about a 24 percent budget reduction for overall facility management and operations. More recently, Australia, a 6.3 percent partner in 2015, first moved to a limited-term collaboration and then ceased involvement entirely in late 2017. The Republic of Korea had a similar limited-term, year-to-year arrangement for a four-year period through the end of 2018, though has since become a full Participant in the Gemini International Agreement. With a 5.0 percent share, Korea has essentially replaced the loss in revenue incurred when Australia left the partnership. The current Agreement between the six Gemini Participants expires in December 2021. At a recent Assessment Point (November 2018), all Participants in the Agreement expressed their desire to remain in the partnership at current participation levels beyond December 2021. The details of a new Agreement are to be established over the next two to three years.

Re-competition of the management and operation of Gemini was last conducted in 2014-2015. The National Science Board authorized a new cooperative agreement with AURA in February 2016 that covers January 2017 through December 2022. Depending on the success of the National Center for Optical-Infrared Astronomy (see section on National Optical Astronomy Observatory in this chapter), NSF will determine in FY 2020 whether to recompete the Gemini management, renew the cooperative agreement, or extend the cooperative agreement to facilitate its integration into the National Center for Optical-Infrared Astronomy and a future management competition.

GEODETIC FACILITY FOR THE ADVANCEMENT OF GEOSCIENCE (GAGE) — $12,640,000 / -$20,000 / -0.2%

Geodetic Facility for the Advancement of GEoscience Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual: Amount	Percent
$12.66	-	$12.64	-$0.02	-0.2%

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. GAGE focuses 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 119 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 111 associate members from foreign institutions. GAGE was formed in late FY 2013 from the geodetic component of the EarthScope facility and related geodetic facilities previously managed by UNAVCO. The FY 2020 Budget Request will enable GAGE to continue to provide key services for the geoscience research community, including global and regional observing networks, field and technical support for experiments worldwide, data management and distribution systems, and other related activities.

Over the last three decades, the Earth science research community has greatly refined our ability to determine the position and motion of points on Earth’s surface using space geodetic techniques, enabling high-resolution studies of Earth processes in a wide range of fields. 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 understand the complex interplay between climate dynamics, continental ice sheet and mountain glacier dynamics, crustal isostatic adjustments, and sea level change are of foremost relevance to current global issues confronting humanity.

Total Obligations for GAGE
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$12.66	-	$12.64	$12.64	$12.64	$12.64	$12.64	$12.64

[1] Outyear estimates are for planning purposes only.

To serve the research needs of the broad Earth science community, GAGE is organized under three primary service areas:

Geodetic Infrastructure

- Currently, the Network of the Americas (NOTA) includes 1,257 continuous Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) stations (more than 800 of which transmit data in real-time with sub-second latency) distributed across the U.S., Mexico, and the Caribbean, with focus on the active plate boundaries. The FY2020 request includes funds support a network that includes about 1100 stations.
- The GAGE facility also provides operational and maintenance support for a network of 76 borehole

strainmeters and 79 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (26) and pore pressure sensors (23) are also collocated with the other borehole instruments. Together, data collected by these instruments enable scientists to study the full range of deformation in the solid Earth, from the rapid shaking associated with earthquakes, through more gradual motions related to slow slip events on faults and to Earth's evolving water cycles, up to long-term plate tectonics.

- Global geodetic arrays outside of the NOTA footprint are supported by GAGE in partnership with investigators. Eight hundred continuous GPS stations from over 60 networks around the world are now maintained and monitored, and have their data compiled into the GAGE data system. In addition, GAGE provides operational and maintenance support for 58 National Aeronautics and Space Administration (NASA)-supported stations, and the GNSS network that supports satellite orbit and clock corrections and the refinement of the International Terrestrial Reference Frame (ITRF). The ITRF is the foundation for high-precision global Earth science and other applications of geodesy such as land surveying.
- Community GPS/GNSS receiver and geodetic technology pool consists of over 700 GPS and GNSS receivers, ancillary equipment, and six terrestrial laser scanners, which can be used by investigators for short- and long-term deployments on research projects supported via multiple Earth and Polar Programs science programs funded by NSF.
- GAGE supports the polar GPS network in Antarctica (ANET) 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 300 terabytes of data from GPS, laser scanning, Synthetic Aperture Radar (SAR), and borehole geophysical instruments from all GAGE components including NOTA, global continuous geodetic 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. UNAVCO, as the manager of GAGE, brokers for cost-effective community access to the SAR imagery acquired by foreign SAR satellite systems.
- In the last quarter of FY 2018, more than 5,000 unique users downloaded data from the GAGE archive. These data enable the wide range of Earth science studies described above.

Education and Community Engagement

- The GAGE Education and Community Engagement 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.
- Scientific community activities include scientific and technical workshops that bring together the international geodetic 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.
In addition to its role in providing 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 by maintaining the Global GNSS Network (GGN). GGN 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 which is now a mainstay of their industry. GPS is also used extensively for terrestrial and marine navigation both commercially and by the general public. The economic impact of access to these data has not been quantified but is clearly substantial.

Management and Oversight

- NSF Structure: The Division of Earth Sciences (EAR) in GEO, through its Instrumentation and Facilities program, provides general oversight of GAGE to 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. In addition, an Integrated Project Team consisting of representatives from EAR, Division of Acquisition and Cooperative Support, and the Large Facilities Office work with the cognizant program officer in addressing challenges and identifying potential barriers for success. The EAR Division Director and Integrated Activities Section Head provide other internal oversight.
- External Structure: GAGE is managed and operated by UNAVCO, which is incorporated as a non-profit consortium representing 119 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: In FY 2019 EAR will conduct a joint review of the data services activities of GAGE and its seismic facility counterpart Seismological Facility for the Advancement of GEoscience (SAGE).

Renewal/Recompetition/Termination

A successful NSF merit review of the proposal for the GAGE facility took place in 2017 and 2018, and funding for the current GAGE cooperative agreement began in FY 2019 and it will end in FY 2023. In preparation for the next recompetition that will begin in FY 2022, NSF will be engaging in two separate activities. First, NSF has requested the National Academy of Science, Engineering, and Medicine, through the decadal study "*Catalyzing Opportunities for Research in Earth Sciences*"[1], to explore different models to manage geophysical capabilities to serve the Earth Sciences community. Second, NSF will convene an interagency working group to identify the needs other agencies have for the capabilities currently provided by SAGE and GAGE. The information from these two activities will be used to draft the solicitation requesting proposals to support geophysical capabilities for Earth Sciences research and education.

[1] www8.nationalacademies.org/pa/projectview.aspx?key=51287

ICECUBE NEUTRINO OBSERVATORY (IceCube) **$7,000,000**
$0 / 0%

IceCube Neutrino Observatory Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$7.00	-	$7.00	-	-

IceCube is the world's first high-energy neutrino observatory and is located deep within the ice cap under the U.S. Amundsen-Scott South Pole Station in Antarctica. With the discovery in 2013 of the very high-energy (PeV) 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. 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 number of neutrinos, detected by IceCube in the range between 100 TeV and 10 PeV has already exceeded 150, and so will provide a statistically robust basis for determining the extrasolar neutrino flux.

Approximately one cubic kilometer of ice is instrumented with photo-multiplier (PM) tubes to detect neutrino-induced, charged reaction products that are produced when a high-energy neutrino interacts in the ice within or near the cubic kilometer fiducial volume. Since completion in 2010, the IceCube detector has been taking data in its final configuration with an uptime of well over 99 percent. 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 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.

IceCube high energy neutrino observations recently helped to reveal a source for the first time ever, of very high energy cosmic rays. An IceCube telegram on September 22, 2017, reported a well-reconstructed track of a ~290 TeV extraterrestrial muon neutrino that pointed to the location of a bright flaring blazar (a quasi-stellar radio source associated with a supermassive black hole at the center of an active giant galaxy). Three scientific spacecraft (Fermi-LAT, AGILE, SWIFT) and one ground-based telescope (MAGIC) then reported ~100 GeV-level gamma-ray observations from a direction that was consistent within 0.1° from the location of the blazar, previously located by the Fermi Large Area Telescope. Archived IceCube data revealed detection of previous emissions from the blazar. Thus multi-messenger astrophysics, initiated by IceCube findings, provided a first exciting answer to a 106-year old scientific mystery regarding the origin of cosmic rays.

Total Obligations for IceCube
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance (GEO)	$3.50	-	$3.50	$3.50	$3.50	$3.50	$3.50	$3.50
Operations & Maintenance (MPS)	3.50	-	3.50	3.50	3.50	3.50	3.50	3.50
Total	**$7.00**	**-**	**$7.00**	**$7.00**	**$7.00**	**$7.00**	**$7.00**	**$7.00**

[1] Outyear estimates are for planning purposes only.

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 over 300 scientists from 23 U.S. institutions and 24 institutions in 11 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 OPP and MPS'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 external 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 by the Collaboration from the senior international scientific leaders for a two-year term, with an option to be renewed once for at most four consecutive years. At lower levels, project management includes international collaboration representatives, as well as participation by staff at collaborating U.S. institutions. UW has in place an external Scientific Advisory Committee and a Software and Computing Advisory Panel that meet annually and provide written advice to the project. UW leadership, including the Chancellor, provides additional awardee-level oversight.

<u>Operations Costs</u>

Full operations and maintenance in support of scientific research began in FY 2011. The associated costs are and will continue to be shared by the partner funding agencies—U.S. (NSF) and non-U.S. —proportional to the number of PhD researchers involved (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.

Approximately $4.0 million annually is provided in NSF support for U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades is provided in response to merit-reviewed proposals, through research grants.

The general operations of South Pole Station, reported in the Antarctic Facilities and Operations 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 U.S. 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. The award's mid-term panel review is currently scheduled for March 2019 and will provide an important basis for future recompetition considerations.

INTERNATIONAL OCEAN DISCOVERY PROGRAM (IODP) **$45,800,000**
-$1,750,000 / -3.7%

International Ocean Discovery Program Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$47.55	-	$45.80	-$1.75	-3.7%

The International Ocean Discovery Program 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 23 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.

Total Obligations for IODP
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$47.55	-	$45.80	$45.80	$45.80	$45.80	$45.80	$45.80

[1] Outyear 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. Due to the long lead-time in planning IODP science expeditions, the FY 2020 Request of $45.80 million for operations and maintenance of the *JOIDES Resolution* will support up to four expeditions per year in the ship's calendar year 2022 schedule. The exact number and the complexity of the expeditions will be determined when the final FY 2020 Appropriation information becomes available. Another commercial contractor provides down-hole-logging services. 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) for FY 2019 are projected to be approximately $8.50 million, funded separately through the Division of Ocean Sciences (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 use 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.

The importance of scientific ocean drilling is underscored by these remarkable facts—since its inception, scientists from 98 countries have participated, resulting in more than 35,000 publications of which more than 11,000 were peer-reviewed, and more than 700 theses and dissertations. U.S. scientists serve as first authors on about 40 percent of the papers currently being published. U.S. scientists from over 150 universities, government agencies, and industrial research laboratories participate in the program. 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.

Management and Oversight

- NSF Structure: OCE in 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 one Program Director dedicated to its oversight. The Program Director has responsibility for three cooperative agreements supporting IODP:
  - *JOIDES Resolution* operations;
  - IODP Science Support Office; and 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, using 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 University of California, San Diego was selected, through a competitive merit-review process, to host the the IODP Science Support Office through award of a five-year (FY 2014—FY 2018) cooperative agreement. In January 2018, following external merit-review of a renewal proposal, NSF awarded a 5-year cooperative agreement for continued support of this Office through FY 2023.

In FY 2014, through a competitive process, Texas A&M University was selected to be the *JOIDES Resolution* Science Operator (JRSO) under a five-year (FY 2015—FY 2019) cooperative agreement which may be renewed for a second five-year period subject to successful performance. 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. The National Science Board in February 2019 authorized the NSF Director, at her discretion, to enter into a new cooperative agreement from October 1, 2019 through September 30, 2023.

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 external merit-review, 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). NSF has initiated the external merit-review process for considering a five-year renewal of the award.

JOIDES Resolution underway for science expedition 369, October 2017. *Credit: Gabriel Tagliard*

LARGE HADRON COLLIDER (LHC) – ATLAS AND CMS

$20,000,000
-$12,460,000 / -38.4%

Large Hadron Collider Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$32.46	-	$20.00	-$12.46	-38.4%

[1] Includes $16.60 million for HL-LHC development and design.

The LHC, an international project at the European Organization for Nuclear Research (CERN) laboratory in Geneva, Switzerland, is the most powerful particle accelerator ever constructed. It produces the highest energy particle beams ever created at a laboratory, making it the premier facility in the world for research in elementary particle physics. The LHC consists of a superconducting particle accelerator, approximately 16.5 miles in circumference, providing two counter-rotating proton beams with a design energy of seven TeV (one TeV=10^{12} electron volts) per beam. It can also provide colliding beams of heavy ions, such as lead. Major "high luminosity" upgrades to the accelerator and detectors are planned to be installed during a suspension in operation that is planned for 2024-2025 to significantly enhance performance of the accelerator and detectors to gather more than ten times the total amount of data collected previously.

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 45 international funding agencies provide support for scientists to participate in experiments at the LHC. Participating scientists have self-organized into distinct scientific collaborations to operate each of the detectors at the LHC. U.S. participation in the LHC scientific program is defined by Memoranda of Understanding and supporting agreements between NSF, the Department of Energy (DOE), and CERN. CERN is responsible for carrying out the overall LHC program goals of operation and maintenance, planning and implementing upgrades to the accelerator, detectors, and research infrastructure, and achieving scientific goals. As the host laboratory, CERN is responsible for coordinating international participation in the LHC program. The U.S., through a partnership between the DOE and NSF, made major contributions to the construction and operation of the A Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) detectors, two large general-purpose particle detectors at the LHC, while NSF additionally supports a strong research team, of modest size, who participate in the LHCb experiment, a special purpose detector that focuses on studying the properties of elementary particles containing b and anti-b quarks. Researchers funded by NSF and DOE comprise the U.S.-ATLAS and U.S.-CMS collaborations, while the U.S.-LHCb collaboration is supported only by NSF. Currently, about 1,270 U.S. researchers participate in the ATLAS and CMS collaborations, including more than 100 post-doctoral fellows and about 450 students, of whom more than 250 are undergraduates. They comprise about 25 percent of the total membership of each international collaboration. NSF supports about 20 percent of the U.S. ATLAS and CMS contingent (plus about 30 of the 1,282 members of the LHCb collaboration).

LHC data have resulted in major scientific discoveries. Foremost of these was the July 2012 announcement by the ATLAS and CMS 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 at the LHC led to the award of the 2013 Nobel Prize in Physics to François Englert and Peter Higgs. In 2018, the ATLAS and CMS collaborations announced observations of Higgs bosons coupling to pairs of top and bottom quarks. Observing these extremely rare processes is a significant milestone for the field of High-Energy Physics as it allows physicists to test critical parameters of the Higgs mechanism in the Standard Model. The new results may also provide insight into one of the most puzzling aspects of the Standard Model: the wide range of masses among fermions, the class of particles that constitute matter and includes quarks and leptons. This analysis relied on the abundant data produced to confirm, with overwhelming statistical significance, that the strengths of these couplings are consistent with the predictions of the Standard Model.

The ATLAS and CMS collaborations continue to search for evidence of new physical phenomena beyond the Standard Model. The overall LHC research program includes searches for particles predicted by various proposed extensions to the Standard Model. These searches utilize the Higgs boson as a tool for discovery: investigating how it interacts with itself, searching for its possible coupling to dark matter, and scrutinizing the data for anomalies indicative of unanticipated phenomena. Despite no conclusive signs of new physics so far, the experimental results to date have helped tighten constraints on different models and possibilities, homing in on the most exciting areas of investigation ahead. Further accumulation of data enables these investigations to be carried out with ever-greater precision as researchers look for small, but statistically significant, deviations of measurements from theoretical predictions.

This FY 2020 Budget Request for the NSF LHC program funds operation and upgrade planning activities by U.S. university-based researchers participating in high energy physics at the LHC. In FY2018, LHC operations were reduced by $2.0 million while planning for the high luminosity upgrade was underway. In FY 2020, HL-LHC planning will have been completed and construction will begin; as LHC resumes full-time operations, the $2.0 million is restored and an additional $2.0 million is provided to cover anticipated increases in operations costs.

Total Obligations for LHC

(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	**ESTIMATES**[1]				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$15.86	-	$20.00	$20.00	$20.00	$20.00	$20.00	$20.00
Development & Design[2]	16.60	-	-	-	-	-	-	-
Total	**$32.46**	**-**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**

[1] Outyear estimates are for planning purposes only. The current cooperative agreements end in December 2021 (CMS) and January 2022 (ATLAS).

[2] The FY 2018 Actual reflects $7.50 million of funding for FY 2019 and FY 2020 HL-LHC development and design. No additional funds are expected in these years.

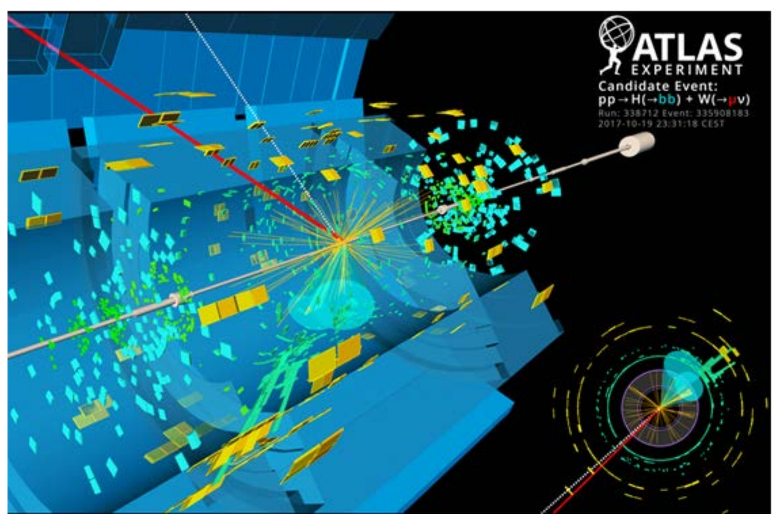
A world-wide cyber-infrastructure, the LHC grid, is dedicated to LHC data processing, allowing scientists to remotely access and analyze vast data sets. The U.S.-ATLAS and U.S.-CMS collaborations continue to lead the development and exploitation of distributed computing within their respective international collaborative efforts. The LHC grid and the Tier 2 computing centers funded by NSF enable the researchers at 92 U.S. universities and five national laboratories to access LHC data and computing resources and thus train students in both state-of-the-art science and computational techniques.

The High Energy Physics Advisory Panel, through the May 2014 report of its Particle Physics Project Prioritization Panel, 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 including the planned high luminosity upgrades which will increase the luminosity, or proton-proton interaction rate, tenfold. This will necessitate significant enhancements to the detectors to exploit this scientific opportunity. NSF has been working with the U.S.-ATLAS and U.S.-CMS collaborations to plan for a possible contribution to this upgrade. Supplemental funds provided through the LHC operations award in FY 2016-FY 2018 enabled the U.S.-ATLAS and U.S.-CMS collaborations to undertake significant preconstruction planning. This resulted in a robust project definition that is the basis for the MREFC funding request. These supplemental funds also enable ongoing activities intended to prepare and complete construction-ready planning. Subject to final NSB authorization, NSF proposes to begin funding elements of the high luminosity detector upgrades to ATLAS and CMS in FY 2020 if construction funding (requested in the MREFC section of this year's NSF Budget Request) is appropriated.

Through the participation of young investigators, undergraduate and graduate students, and minority institutions, the U.S.-LHC program 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 MPS Division of Physics is responsible for day-to-day project oversight. The Division of Acquisition and Cooperative Support in BFA provides financial and administrative support. An Integrated Project Team, with representatives from MPS, experienced program officers from other directorates within NSF, the Large Facilities Office (LFO) and other divisions in BFA, contributes to the planning and oversight activities supporting NSF's FY 2020 Request for MREFC funding to commence constructing the high-luminosity detector upgrades. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight.
- 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 U.S. CMS and with Stony Brook University for U.S. ATLAS.
- Reviews: NSF and DOE conduct separate and joint external reviews of operation and detector upgrade activities so that each agency is fully cognizant of the activities of the other partner. Two joint review meetings per year assess operational performance, scientific and financial status, management issues, and plans for future activities. The most recent JOG was held in October 2018. The next major joint review will be held in June 2019. NSF also conducts external reviews of planning for the proposed high luminosity upgrades. The Final Design Reviews are scheduled to be held in September 2019. In addition, business reviews are conducted regularly by LFO and the Division of Acquisition and Cooperative Support in BFA. An independent cost estimate will be performed in support of the NSF cost analysis for the construction award.



A candidate event display for the production of a Higgs boson decaying to two b-quarks (blue cones), in association with a W boson decaying to a muon (red) and a neutrino. The neutrino leaves the detector unseen and is reconstructed through the missing transverse energy (dashed line). *Credit: ATLAS Collaboration/CERN.*

Renewal/Recompetition/Termination

Funding for operations and maintenance for the NSF LHC program was renewed in FY 2017 following external review of proposals from ATLAS and CMS. NSF's review process culminated in the implementation of cooperative agreements for operation that will expire in FY 2022. ATLAS and CMS periodically conduct internal competition among the U.S. universities within each collaboration to select the NSF PI and host institution for the Cooperative Agreement for operation. This process preceded the current awards, and it will be repeated prior to submission of the LHC operations proposal in FY 2022.

LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY (LIGO) $45,000,000 -$4,430,000 / -9.0%

Laser Interferometer Gravitational-Wave Observatory Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$49.43	-	$45.00	-$4.43	-9.0%

[1] FY 2018 Actual includes $10.0 million in additional FY 2018 funding above the requested amount.

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 September 14, 2015, NSF's 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. In October 2017, LIGO announced the first detection of a neutron star-neutron star merger, observed on August 17, 2017. This event was also observed in the electromagnetic spectrum, from gamma rays to radio waves, by 70 telescopes around the world. These observations had the far-reaching consequence of confirming that most of the elements heavier than iron were produced by neutron star-neutron star mergers. The 2017 Nobel Prize in Physics was awarded to Barry Barish, Kip Thorne, and Rainer Weiss for their "decisive contributions to the LIGO detector and the observation of gravitational waves."

In two separate observational periods beginning with the September 14, 2015 detection, LIGO has now detected gravitational waves from 10 stellar-mass binary black hole mergers as well as the one binary neutron star inspiral. During the first observing period, or "run" (O1), from September 12, 2015 to January 19, 2016, gravitational waves from three binary black hole mergers were detected. The second observing run (O2), which lasted from November 30, 2016, to August 25, 2017, saw a binary neutron star merger and a total of seven binary black hole mergers. GW170729, the third event detected in O2 on July 29, 2017, is the most massive and distant gravitational wave source ever observed. In this coalescence, which happened approximately five billion years ago, an equivalent energy of almost five solar masses was converted into gravitational radiation.

The European Advanced Virgo interferometer joined NSF's two Advanced LIGO detectors on August 1, 2017, in O2. While the LIGO-Virgo three-detector network was operational for only three and a half weeks, five events were observed in this period. One of these, GW170814, was the first binary black hole merger measured by the three-detector network, enabling the first measurements of gravitational wave polarization and providing an additional confirmation of the theory of general relativity. The Virgo interferometer also contributed to the detection of the binary neutron star merger.

All these observations were made while LIGO is still in the process of fine-tuning its instrumentation to reach design sensitivity. Advanced LIGO is currently preparing for a third scientific run beginning in 2019, and a fourth beginning in 2021, incrementally increasing its sensitivity to reach the full capabilities of the current suite of instrumentation.

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 four-km length is only about 1/1000th the diameter of a proton. LIGO's four-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 between a gravitational wave and local sources of noise.

In 2015, LIGO completed installation of the "Advanced LIGO" upgrade, funded through the MREFC account. The upgrade enabled the design, fabrication, and installation of an improved apparatus expected to increase LIGO's sensitivity 10-fold relative to the initial LIGO apparatus (which had operated through 2009). During O1, the Advanced LIGO interferometers operated at about four times the initial LIGO sensitivity, and at about six times the initial sensitivity during O2. LIGO's O3 goal is an eight-fold increase.

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 scientific value of obtaining complementary gravitational wave and electromagnetic signals from the same source has already been demonstrated in the recent observation of a neutron star-neutron star merger. As the number of observations expands with enhanced sensitivity and localization, this will significantly increase our understanding of supernovae and neutron stars. Such scientific prospects help motivate the NSF Big Idea 'Windows on the Universe.'

Total Obligations for LIGO

(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$39.43	-	$44.60	$45.00	$45.00	$45.00	$45.00	$45.00
Facility Upgrades[2]	10.00	-	0.40	-	-	-	-	-
TOTAL REQUIREMENTS	**$49.43**	**-**	**$45.00**	**$45.00**	**$45.00**	**$45.00**	**$45.00**	**$45.00**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in September 2023.

[2] FY 2018 Actual includes $10.0 million in additional FY 2018 funding above the requested amount.

Facility Upgrades: LIGO researchers are planning a series of instrumental upgrades to take place in the coming years. The first of these enhancements, known as Advanced LIGO Plus (or "A+"), will increase the volume of space surveyed by Advanced LIGO by a factor between four and seven, depending on the type of gravitational wave source. In FY 2018, NSF awarded $10.0 million to LIGO for the A+ enhancement, with an additional $10.47 million expected to be provided in FY 2019. This award is part of an international effort between NSF, the UK Research and Innovation (UKRI) and the Australian Research Council (ARC), who jointly support the U.S.-UK-Australian collaboration of researchers spearheading A+. The A+ upgrades are expected to start operating in 2024.

LIGO is pursuing an integrated program of periodic scientific operation of the LIGO observatories, interleaved with engineering studies and upgrades that continue to enhance operating performance. 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 public outreach (EPO) 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 the Washington State Tri-Cities region, reaching approximately 10,000 people each year. In 2018, LIGO Laboratory secured funding from Washington State for the conceptual design of a LIGO Hanford STEM Exploration Center to carry out a high-impact, interactive EPO program similar in mission to the LIGO SEC. LIGO Laboratory/Caltech plans to submit a construction proposal to the Washington State House of Representatives in 2019. LIGO Laboratory members supported by the operations budget also contribute to many activities of the EPO working group of the LIGO Scientific Collaboration.

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 technological developments at LIGO 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 108 collaborating institutions in 20 countries with nearly 1,300 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 and exploring future technologies, as well as fostering education and public outreach programs. NSF supports LSC activities in the United States at approximately $8 million per year, which is provided through regular disciplinary program funds.

Management and Oversight

LIGO activities are funded through a five-year cooperative agreement that began October 1, 2017. 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 operations that examine performance relative to objectives defined in LIGO's annual work plans. Infrastructure refurbishments recently accomplished, such as repairs and improvements to the vacuum system, as well as further work planned in 2020 will extend the facility life beyond 2030.

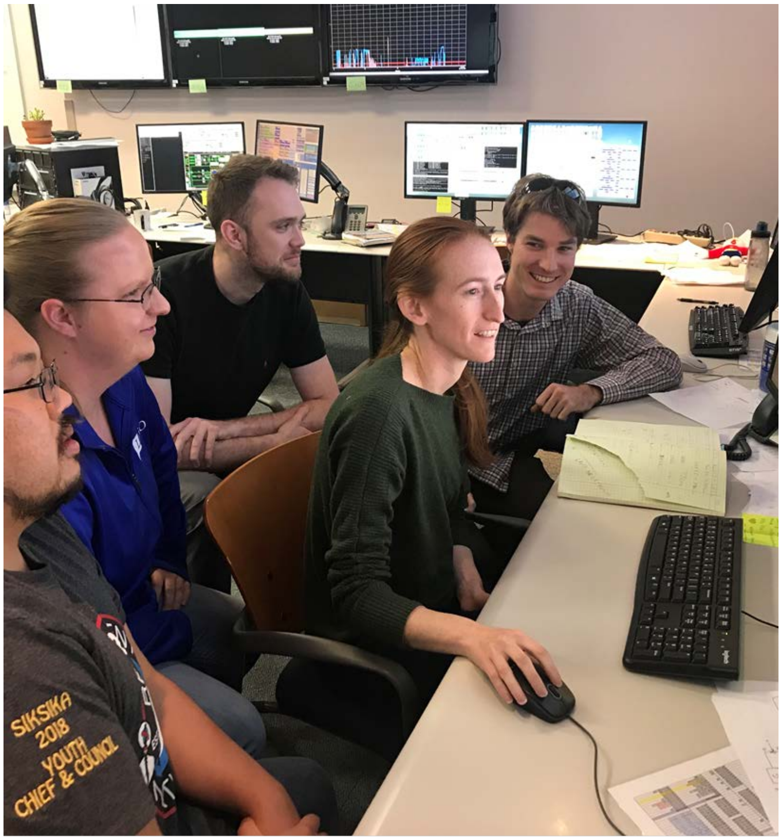
- NSF Structure: NSF oversight is coordinated internally by the LIGO program director in the MPS Division of Physics. The program director consults regularly with representatives from the Large Facilities Office and the NSF Division of Acquisition and Cooperative Support in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.
- External Structure: LIGO is managed by the California Institute of Technology under a cooperative agreement. A subaward from California Institute of Technology to Massachusetts Institute of Technology supports a team of scientists and engineers that are fully integrated into all LIGO activities.

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 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 most recent annual review was held in June 2018. The next annual review is planned for June 2019.

Renewal/Recompetition/Termination

In 2015 and 2016 MPS conducted a detailed consideration of whether to recompete the management of the LIGO Laboratory in conjunction with the current five-year award. As LIGO had just completed installation of the Advanced LIGO apparatus in early 2015, and its operational activities were focused on initial commissioning of the apparatus, NSF concluded recompetition was inappropriate. The NSB was apprised of this at their August 9-10, 2016 meeting, and the award was renewed for the period of October 1, 2018 to September 30, 2023. The 2015 study recommended that NSF, in partnership with the LIGO Scientific Collaboration and with input from the broader astrophysics community, again consider the circumstances and criteria for a possible recompetition midway through the current five-year period (i.e., 2020-21).



Scientists and graduate students in the LIGO Hanford Observatory control room conducting a series of experiments to improve the Hanford interferometer sensitivity. *Credit: Caltech/LIGO Laboratory.*

THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON) $62,600,000

-$5,300,000 / -7.8%

The National Ecological Observatory Network Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$67.90	-	$62.60	-$5.30	-7.8%

[1] FY 2018 Actual includes $3.0 million in additional FY 2018 one-time funding above the requested amount.

The most persistent challenges facing the ecological sciences today are a result of our limited understanding of the complex interactions between living and non-living systems operating over large spatial and temporal scales. Critical global challenges such as ecological effects of increasing atmospheric carbon dioxide land-use change, emerging infectious diseases, and invasive species highlight the complexity of key processes that are connected across large spatial scales and play out over decades. As these and other threats arise more frequently and spread rapidly across continents, it is critical to scientific progress that the short- and long-term effects of these phenomena be systematically monitored and assessed, as well as become more predictable through mathematical and statistical modeling.

Assessment of ecological processes at a continental scale has been hindered by a lack of infrastructure to enable the research required to address complex ecological issues at the necessary spatial and temporal scales. NEON was designed to address this lack of infrastructure and enable vital research. NEON consists of 81 strategically located field sites, across 20 eco-climatic domains, with instruments, sensors, cameras, and manual biological sampling networked into an integrated research platform for regional- to continental-scale ecological research. The sensor networks, instrumentation, experimental infrastructure, natural history archive facilities, and remote sensing are linked via the internet to computational and analytical capabilities to create NEON's integrated infrastructure.

NEON was constructed to revolutionize ecological research and engage the research and education communities in the use of open data. In doing so, it provides over 170 standardized data products including meteorological, soil, organismal, biogeochemical, freshwater and remote sensing data for ecosystems at various temporal and spatial scales across the United States over a 30-year timeframe.

Using NEON data, scientists across the U.S. are now able to conduct regional- to continental-scale research projects on the fundamental biological processes underlying invasive species, emerging diseases, changing biogeochemical cycles, land-use changes, climatic variation, and biodiversity, as well as other grand challenges in ecological science. Researchers can also arrange to use the Observatory's infrastructure (field sites, instrumentation, airborne remote sensing, etc.) for their own studies to advance understanding of ecological processes.

Current Status

Battelle Memorial Institute (Battelle) is the current awardee for management of NEON. Battelle is a non-profit professional management organization that operates a number of scientific and technical facilities. Construction of NEON is 99 percent complete and expected to be concluded in mid-FY 2019. NEON is collecting and analyzing biological and chemical samples, measuring physical properties, transmitting sensor data to headquarters, and delivering processed datasets and data products via the NEON data portal. Cyberinfrastructure enhancements are underway including some for the data center connectivity and site sensor data processing. Battelle is implementing community engagement plans that will support overall utilization of the data and resources that are now available to the community. The research community is beginning to use NEON data and infrastructure in its research as evidenced by the increase in the number of awards in FY 2018, and the number of presentations at recent Ecological Society of America (31 NEON-related events) and American Geophysical Union (52 NEON-related events) meetings.

Total Obligations for NEON
(Dollars in Millions)

	Prior Years[2]	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
R&RA:									
Development & Design	$104.85	-	-	-	-	-	-	-	-
Operations & Maintenance[3,4]		64.90	-	62.60	62.60	62.60	62.60	62.60	62.60
Cyberinfrastructure Enhancements	-	3.00	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$104.85	$67.90	-	$62.60	$62.60	$62.60	$62.60	$62.60	$62.60
MREFC:									
Implementation	447.48	12.79	-	-	-	-	-	-	-
Subtotal, MREFC Obligations[4,5]	$447.48	$12.79	-	-	-	-	-	-	-
Total Obligations	**$552.33**	**$80.69**	**-**	**$62.60**	**$62.60**	**$62.60**	**$62.60**	**$62.60**	**$62.60**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2020.
[2] Development and design funding and implementation funding are cumulative of all prior years.
[3] Future O&M requests will be based on a more thorough analysis of science capabilities and affordability.
[4] In FY 2016, consistent with the revised total project cost, $20.0 million of FY 2016 R&RA appropriated funding was transferred to the MREFC account. In FY 2017, $5.86 million of FY 2017 R&RA appropriated funding was transferred into the MREFC account.
[5] A total of $14.21 million of FY 2017 MREFC funding was carried over into FY 2018. Of this amount, $12.79 million was obligated in FY 2018 to complete project construction requirements. Approximately $1.4 million is being held by NSF to mitigate remaining risks.

Cyberinfrastructure Enhancements: The cyberinfrastructure enhancements funding will support integration of up-to-date cyberinfrastructure components to strengthen NEON's ability to meet expected data delivery capabilities and user expectations. This will be accomplished through re-engineering and updating some aspects of NEON's data-gathering, processing, and storage infrastructure. Components of NEON's cyberinfrastructure, include the Grouped Remote Access Peripheral Equipment, the instrumented systems transition pipeline, the data portal and programming interface, and data center security, have been identified for improvement. Enhancements on these components will improve data volume handling, processing capacity and capability, data discoverability and accessibility, and data security.

Management and Oversight

NSF Structure:

The NEON program is managed in BIO, with the Office of the Assistant Director (BIO/OAD) providing policy and programmatic guidance. Oversight resides within the Division of Biological Infrastructure (DBI) and Division of Environmental Biology (DEB). The NEON Program team within BIO consists of DBI and DEB senior managers, program officers, and a project manager. The Integrated Project Team (IPT), chaired by the NEON cognizant program officer and which includes representatives from the BFA Large Facilities Office (LFO) and the BFA Division of Acquisition and Cooperative Support, with additional participation from the Office of Legislative and Public Affairs, BFA Division of Institution and Award Support-Cost Analysis and Pre-Award Branch, Office of General Counsel, Office of International Science & Engineering, and the Office of the Director, as necessary, provides guidance and advice in the review and oversight of the project.

External Structure

In the Spring of 2016, leadership and management of the NEON project was transferred to Battelle, which oversees all aspects of project implementation and coordinates observatory operations. Within Battelle, the observatory director/chief scientist (OD/CS) provides overall scientific leadership and interfaces with the science community and other entities to support the scientific priorities and operations of NEON. A Science, Technology, and Education Advisory Committee (STEAC), composed of members of the NEON user community, provides oversight and guidance to the project and helps ensure that NEON will enable frontier research and education. The work of the STEAC is complemented by several Technical Working Groups that advise Battelle on the technical aspects of the project.

Reviews

A construction close-out review, scheduled for CY 2019, will document the completion of NEON construction scope and transition to operations. External evaluators will be tasked to review project documentation and confirm delivery of observatory capacity. Reviews of full operations and maintenance (O&M) are held annually. The first O&M review was held in July 2018, during which external reviewers were charged with the evaluation of details of NEON operations including: data collection, data delivery, community engagement, education and outreach, NEON's biorepository, cyberinfrastructure, cost performance, and risk management. The next review of O&M, emphasizing data availability and quality, is planned for summer of 2019. Progress against the annual program plan and towards implementation of review recommendations is also monitored by BIO via biweekly teleconferences, bimonthly operations reports, and site visits as needed. In addition to these scientific and technical reviews, there are periodic reviews by organizations within BFA.

Operations Costs

Operations and maintenance support began in FY 2014. In August of 2017, a supplemental operations award was authorized. For planning purposes, costs are held constant by BIO at the projected annual operations ceiling of $65.0 million, pending further evaluation of the time phased cost-proposal submitted by Battelle and identification of further operating efficiencies.

Community Engagement

Battelle's community engagement efforts are led by the OD/CS. The community engagement programs facilitate increased awareness and understanding of ecological change and familiarize people with large, complex datasets. Staff are educating NEON users and the public through a YouTube channel,[1] presentations at local and national meetings, workshops and data institutes, and online learning modules. The data science team is facilitating access to and use of the data with open-source software packages and utilities. BIO and its Advisory Committee have assembled a subcommittee, composed of members of the research community, to evaluate engagement models that will inform a community-based strategy for mobilizing and sustaining NEON users. BIO also engages with other federal stakeholders, including Defense Advanced Research Projects Agency, Department of Energy, Department of Interior (DOI)/National Invasive Species Council (NISC), Department of Agriculture (USDA), DOI National Park Service, USDA Agricultural Research Service, United States Geological Survey, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the Smithsonian Institution. Federal stakeholders are engaged through the NEON Interagency Working Group to help maximize the scientific impact of NEON through coordination when advantageous to the project.

Renewal/Recompetition/Termination

The current O&M award to Battelle began in November 2017 and ends in October 2020. An additional 12 months of funding to Battelle was also authorized but is to be awarded at the NSF Director's discretion for FY 2021. NSF is using established large facility processes to evaluate options for subsequent support to ensure continuity of operations beyond the current award.

[1] www.youtube.com/neonscience

NATIONAL HIGH MAGNETIC FIELD LABORATORY (NHMFL) $36,780,000 -$17,380,000 / -32.1%

National High Magnetic Field Laboratory Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 20 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$54.16	-	$36.78	-$17.38	-32.1%

[1] The FY 2018 Actual includes $10.08 million in additional FY 2018 one-time funding above the requested amount and $9.34 million to fund part of FY 2019 costs.

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. The laboratory is managed by Florida State University (FSU), and consists of facilities at FSU, the University of Florida (UF), and Los Alamos National Laboratory (LANL). 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. There are approximately 1,700 users per year, including faculty and staff at the three host institutions. Stewardship and oversight of NHMFL is provided through the MPS Division of Materials Research (DMR), and the Fourier Transform Ion Cyclotron Resonance (FT-ICR) facility within NHMFL is overseen by the MPS Division of Chemistry (CHE).

The laboratory is an internationally recognized leader in magnet design, development, and construction, including the development of new superconducting materials. Many unique magnet systems have been designed, developed, and built by the Magnet Science and Technology Division of NHMFL. Since 2012, the laboratory has held the world's record for the highest nondestructive, pulsed magnetic field at 100.75 Tesla, a unit of magnetic strength (magnetic flux density). The 45 Tesla magnet currently provides the highest steady-state magnetic fields in the world for user access. This world record has been held for almost two decades. In April 2017, NHMFL's new 36 Tesla Series-Connected Hybrid (SCH) magnet reached its performance milestone of no change in magnetic field stability and homogeneity greater than one part per million (ppm) across the sampling volume. This stability has enabled the world's first nuclear magnetic resonance spectrum at 1.5 GHz, which opens a window for chemists and biologists to probe greater numbers of elements in the periodic table. Prior to this milestone, the previous record was set at 1.0 GHz. The one-year commissioning period for the SCH magnet ended in Fall 2017 and the magnet was added to the user program in January 2018. Both the 45 Tesla and 36 Tesla magnets enable scientists to gain new insights into the electronic structures of novel materials such as graphene, topological insulators, and high temperature superconductors.

The 21 Tesla FT-ICR spectrometer opened for user operations in October 2015. This instrument 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.

A major scientific impact from NHMFL is expected from the research on quantum materials conducted by researchers using the record-setting NHMFL magnets. These magnets allow for the exhibition, identification, and visualization of new and unusual quantum effects that lead to deeper understanding of quantum materials and enable the discovery of new ones. Another example of an area of great potential is new imaging techniques for studying the brain. Magnetic resonance imaging and functional magnetic resonance imaging are currently based on imaging proton spin density and intrinsic tissue relaxation rates. With higher magnetic field strengths, NHMFL is investigating other nuclei to use that would result in new insights into mapping the brain and neuroscience.

NHMFL collaborates with more than 60 private sector companies as well as a number of national laboratories. These include those supported by the Department of Energy, such as Oak Ridge National Laboratory, which hosts the Spallation Neutron Source, and Argonne National Laboratory, which hosts the Advanced Photon Source. Additionally, NHMFL collaborates internationally. The laboratory delivered and commissioned a 26 Tesla SCH magnet to the Helmholtz-Zentrum Berlin for neutron scattering experiments. Collaborations also exist with the International Thermonuclear Experimental Reactor in France, and national magnet laboratories in several other countries, including France, the Netherlands, and Germany.

NHMFL provides a unique interdisciplinary and convergent learning environment. The Center for Integrating Research and Learning at NHMFL conducts education and outreach activities, which include a Research Experience for Undergraduates program, summer programs for teachers, a summer camp for middle school girls, and activities to raise the scientific awareness of the general public.

Total Obligations for NHMFL

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance (DMR)[2]	$42.33	-	$35.05	$36.10	$37.18	$37.18	$37.18	$37.18
Operations & Maintenance (CHE)	1.73	-	1.73	1.73	1.73	1.73	1.73	1.73
Facility Upgrades[3]	10.08	-	-	-	-	-	-	-
Total	**$54.14**	**-**	**$36.78**	**$37.83**	**$38.91**	**$38.91**	**$38.91**	**$38.91**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2022.

[2] The FY 2018 Actual for DMR includes $9.34 million to fund part of FY 2019 costs.

[3] The FY 2018 Actual includes $10.08 million in additional FY 2018 one-time funding above the requested amount.

Facility Upgrades: In FY 2018, NSF awarded $10.08 million via two supplements: (1) to support the purchase of major equipment in need of refurbishment or replacement ($5.88 million), and (2) to support the first phase of advanced research and development towards the construction of a novel 40 Tesla All-Superconducting Magnet ($4.20 million). The second supplement was provided to address one of the magnet goals recommended by the 2013 report by the National Academies of Science, Engineering, and Medicine (the National Academies) on opportunities in high magnetic field research[1] (see Management and Oversight section).

Management and Oversight

- NSF Structure: NHMFL is supported by DMR, with the DMR program director as the primary contact for most of the laboratory. CHE supports the FT-ICR Facility, which is overseen by a CHE program director. The Division of Acquisition and Cooperative Support (DACS) and the Large Facilities Office (LFO) in BFA provide financial and administrative support and the MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.
- External Structure: A consortium of FSU, UF, and LANL operates NHMFL under a cooperative agreement. FSU, as the agreement signatory, is responsible for administrative and financial oversight and for ensuring that lab operations are consistent with the cooperative agreement. The principal investigator, the NHMFL director, reports to the FSU Vice President for Research. Four senior faculty members are co-principal investigators. The NHMFL director receives guidance primarily from the

[1] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states

NHMFL executive committee, the NHMFL science council, and the NHMFL diversity committee together with recommendations from an external advisory committee and the users' executive committee.

- NSF initiated a community study through the National Academies on opportunities in high magnetic field research. The resulting report titled *High Magnetic Field Science and Its Application in the United States* was released in 2013 and presented to the NSB in May 2014. The report continues to inform future plans for investments in this area, including new magnet developments.
- In 2017, NSF held a workshop, *Exploring Quantum Phenomena and Quantum Matter in Ultrahigh Magnetic Fields,* to identify the most exciting directions of ultrahigh-field research that could impact the understanding of quantum materials. This workshop was informed by the long-term ultrahigh field magnet development recommendations from the 2013 National Academies report.

The National High Magnetic Field Laboratory, Tallahassee, Florida site. *Credit: NHMFL*

<u>Reviews</u>

NSF monitors annual plans and reports including user metrics and conducts monthly teleconferences with the NHMFL director. NSF conducts annual external reviews to assess the user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, as well as operations, maintenance, and new facility development. Annual reviews also assess the status of education, training and outreach, operations and management efficiency, and diversity plans. In addition to these yearly scientific reviews, NHMFL undergoes periodic business systems reviews by LFO and DACS.

Recent and upcoming reviews include:

- Renewal of NHMFL operations award approved by the NSB, August 2017.
- External Safety Review at all three sites of the NHMFL (July and September 2018)
- Site visit review with external panel of experts, November 2018.
- Site visit review with external panel of experts, October 2019.

Renewal/Recompetition/Termination

In May 2015, NSF determined that it was in the best interest of the U.S. science and engineering enterprise to renew rather than re-compete the NHMFL award. A renewal proposal was submitted in May 2016. In August 2017, the NSB authorized an award to FSU for the operation of NHMFL for 60 months starting in 2018. The current award for the operation of the NHMFL started in January 2018 and will end in December 2022.

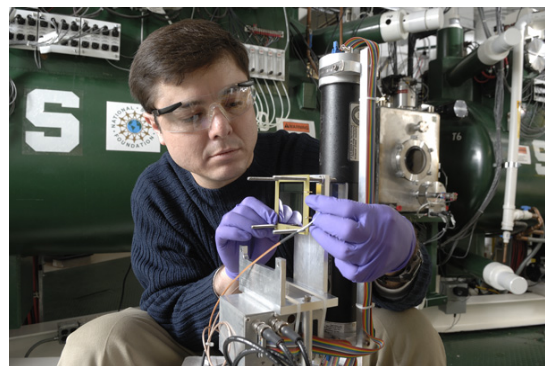
NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY (NSCL) **$22,000,000**
-$2,000,000 / -8.3%

National Superconducting Cyclotron Laboratory Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$24.00	-	$22.00	-$2.00	-8.3%

NSCL is a national user facility based at Michigan State University (MSU). With two linked superconducting cyclotrons, K500 and K1200, it is the leading rare isotope research facility in the United States 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.

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 understanding 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.



Beam physicist Mauricio Portillo in the NSCL beam transfer hall. *Credit: NSCL and MSU*

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 operates 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 proposals for beam use. 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.

Total Obligations for NSCL

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$24.00	-	$22.00	$20.00	-	-	-	-

[1] The current cooperative agreement ends in FY 2021, after which the NSF-managed NSCL will transition to the DOE-managed Facility for Rare Isotope Beams.

Funding for NSCL has always had two components: operations and maintenance of the lab and the research activity of the MSU nuclear scientists whose research is based at NSCL. In FY 2018, the operations and maintenance support totaled $18.0 million and research support totaled $6.0 million. The reductions in FY 2020 and FY 2021 reflect the transfer of a portion of the NSCL research support to the MPS Division of Physics' (PHY) core program, Nuclear Physics, as part of the planned transfer of NSCL operations and maintenance to the Department of Energy in 2022.

Students at a recent Physics of Atomic Nuclei (PAN) Workshop. *Credit: NSCL and MSU*

NSCL supports and enhances doctorate-level graduate education and post-doctoral research experiences. About 10 percent of all doctorates granted in nuclear physics in the United States are based on research at NSCL. The lab also provides research experiences for undergraduate students, K-12 students, and K-12 teachers. In a typical year about 800 users conduct research at NSCL; approximately 70 percent of those users are U.S. scientists.

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 in PHY and other staff, accompanied by external experts. NSF uses the annual site reviews to assess the user program, operations, maintenance, facility efficiency, national and international research developments, and in-house research programs. The NSF program officer monitors lab operations and plans through monthly phone conferences with the NSCL director. The program officer consults regularly with the NSF Large Facilities Office and the NSF Division of Acquisition and Cooperative Support in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.
- External Structure: MSU provides added support for NSCL, which is managed by a director and three associate directors (experimental research, education and 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 looked at results and achievements related to intellectual merit and broader impacts for the prior 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 annual review took place in August 2018. The report expressed overwhelming support for the management and operations of NSCL. The next review is planned for Summer 2019.

Renewal/Recompetition/Termination

NSCL currently operates under a cooperative agreement with MSU, which is due to expire at the end of FY 2021. After that time, NSCL will transition to the new Facility for Rare Isotope Beams (FRIB)[1], 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 FRIB becomes operational. MSU will be the performing institution under a cooperative agreement with DOE for the future FRIB. To facilitate interagency planning and coordinate the transition from the NSF-funded NSCL to the DOE-funded FRIB, a Joint Oversight Group of DOE and NSF personnel has been meeting since 2010. DOE and NSF will coordinate transfer of facility stewardship as it transitions from NSCL to FRIB.

[1] https://frib.msu.edu/

NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE (NHERI) **$11,750,000**
-$10,620,000 / -47.5%

Natural Hazards Engineering Research Infrastructure Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$22.37	-	$11.75	-$10.62	-47.5%

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested amount.

The NHERI program was established in 2015 by NSF as a distributed, multi-user, national research facility for use by the Nation's natural hazards engineering research community. NHERI provides researchers with access to state-of-the-art facilities and tools, unavailable through any other agency, to study the performance of civil infrastructure, including buildings, geostructures, and underground structures, in individual natural hazards and in combinations of natural hazards. These facilities provide essential research infrastructure to support two federally-mandated interagency programs: the National Earthquake Hazards Reduction Program and the National Windstorm Impact Reduction Program.

The portfolio of research investigations, which is funded separately through NSF's highly competitive, parallel proposal evaluation process, involves large-scale experimentation linked to numerical modeling, and collection and sharing of data to increase the knowledge gleaned from investment in these facilities. Such research is essential to the development of more comprehensive and more realistic predictive models of how civil infrastructure responds to earthquakes, winds, storm surges, and tsunamis. These advances, in turn, enable the design of more hazard-resilient civil infrastructure and improve safety for citizens during these events.

The research infrastructure includes earthquake and wind engineering experimental facilities; a wave testing facility; a post-disaster, rapid-response research facility; cyberinfrastructure; computational modeling and simulation tools; and a research data repository. The research infrastructure investment also supports education and community outreach activities.

During FY 2015 and FY 2016, NSF established NHERI 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 (LHPOST) at the University of California, San Diego (UCSD),
- 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
- Post-Disaster, Rapid-Response Research (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 NCO activities include convening the governance groups; working with the NHERI PIs to develop consensus-based policies and procedures for NHERI, and the annual NHERI-wide 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. 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 highly 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 (Discovery Workspace); 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 develops 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 are integrated into the CI awardee's Discovery Workspace.

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 support for research involving NHERI experimental facilities through separate, ongoing research and education programs. The primary NSF program supporting such activities is the Engineering for Civil Infrastructure (ECI) program in ENG's Division of Civil, Mechanical and Manufacturing Innovation (CMMI).

Total Obligations for NHERI

(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[2] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$10.87	-	$11.75	$12.00	$12.00	$12.00	$12.00	$12.00
Facilities upgrade	8.50	-	-	-	-	-	-	-
CONVERGE facility	3.00	-	-	-	-	-	-	-
Total	**$22.37**	**-**	**$11.75**	**$12.00**	**$12.00**	**$12.00**	**$12.00**	**$12.00**

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested amount.

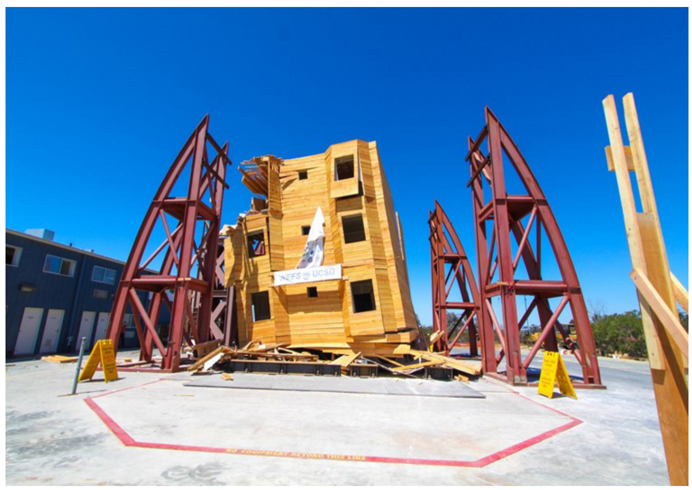
[2] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2020.

In FY 2018, ENG provided $8.50 million to UCSD to upgrade its LHPOST facility from its current one degree of freedom to a full six degrees of freedom capability. In its upgraded configuration, the LHPOST will be able to reproduce all six components of motion (two horizontal and one vertical translational components, as well as pitch, roll, and yaw rotational components) experienced by the ground during earthquakes. In addition, ENG provided an additional $3.0 million to the University of Colorado at Boulder to establish and support a new extreme events reconnaissance research leadership corps that connects researchers from different disciplines, develops best practice guidelines for reconnaissance research, and supports public communications in the event of a major disaster.

Management and Oversight

- NSF Structure: NSF oversight is handled by two program officers in ENG/CMMI working cooperatively with staff from ENG; the Office of Budget, Finance, and Award Management (BFA); the Office of General Counsel; the Office of Legislative and Public Affairs; and the Chief Officer for Research Facilities (CORF) in NSF's Office of the Director. Within BFA, the Large Facilities Office (LFO) provides advice to program staff and assists with agency oversight and assurance.
- 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.
- Oversight: NSF provides oversight to NHERI awardees through cooperative agreements. Awardee operations and activities are reviewed through quarterly and annual project reports (for the 11 cooperative agreements) and an annual report for the CONVERGE grant, submitted by awardees and through site visit and reverse site visit reviews conducted by NSF program officers.

Studies



The above image displays the University of California, San Diego outdoor shake table, which allows large structures to be tested against seismic activity. Here, a wooden building shows damage after testing. *Credit: UCSD/Jacobs School of Engineering.*

- 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 (DCL) NSF 10-071.[1] One study, a workshop held by the National Research Council on Grand Challenges in Earthquake Engineering Research, was completed in FY 2011, and the second study was completed in FY 2012. These studies provided input to NSF for the determination of support for future earthquake engineering research infrastructure beyond FY 2014. The plan to support a smaller "second generation" Network for Earthquake Engineering Simulation (NEES) (NEES2) during FY 2015-2019 was presented to the National Science Board at their July 2012 meeting and described in DCL NSF 12-107.[2] The plan proposed a lower annual operations budget, reflected in the $8.0 million reduction from FY 2014 in NSF's FY 2015 Budget Request, from $20.0 million to $12.0 million, to allow larger investment in earthquake engineering research using NHERI facilities.
- 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.[3]
- In February 2013, NSF released solicitation NSF 13-537 to compete and operate NEES2 for FY 2015-

[1] http://nsf.gov/pubs/2010/nsf10071/nsf10071.jsp
[2] http://nsf.gov/pubs/2012/nsf12107/nsf12107.jsp
[3] www.nist.gov/customcf/get_pdf.cfm?pub_id=915541

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. Those competitions were completed in FY 2016. Awards for NHERI operations involve commitments for five years, contingent on available funds and satisfactory performance.

Renewal/Recompetition/Termination

During FY 2019, ENG is developing a plan for supporting natural hazards engineering research, education, and research infrastructure beyond FY 2020. Those plans are expected to be announced in spring/summer 2019.

OCEAN OBSERVATORIES INITIATIVE (OOI) **$38,000,000**
-$6,080,000 / -13.8%

Ocean Observatories Initative Funding
(Dollars in Millions)

FY 2018 Actual	FY 2018 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$44.08	-	$38.00	-$6.08	-13.8%

The Ocean Observatories Initiative began in FY 2009 as a MREFC construction project. In FY 2016, OOI transitioned from the MREFC construction effort to the management and operations 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. Currently, the OOI delivers data/metadata and education tools to the public via the OOI website[1].

Since the operations and maintenance phase of the project started in January 2016, the OOI CI system infrastructure has served over 150 million user requests and delivered over 100TB of data to users from over 100 distinct countries across the globe.

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

[1] www.oceanobservatories.org

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 can form economically-important mineral deposits, 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 Program Team is successfully operating the in-water instrumentation, transmitting ocean data to storage, and incrementally delivering processed datasets and data products via the website. During FY 2018 the OOI website received over 31 million visits/requests from over 50 countries and approximately 20 T bytes of data were transferred. Annual Work Plan activities for refurbishment and redeployments of the moorings, instruments, and platforms were completed as planned. Data quality management methodology continues to mature with the transfer of this responsbility to the Marine Implementing Organizations under the new award. It includes active outreach by the OOI science team to the science community on the quality assurance/quality control (QA/QC) methods and procedures being used.

Operations plans at the FY 2020 Request level of $38.0 million will be developed in partnership with the awardee and the research community to minimize costs, assess impacts of any proposed de-scope activities, and maximize the scientific return of the facility.

Total Obligations for OOI
(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$44.08	-	$38.00	$38.00	$38.00	$38.00	$38.00	$38.00

[1] Outyear estimates are for planning purposes only.

After approval of a resolution in May 2018 by the National Science Board, NSF entered into a new cooperative agreement with the Woods Hole Oceanographic Institution (WHOI) for operation and management of the OOI and management responsibilities were transferred from the Consortium for Ocean Leadership (COL) to WHOI on October 1, 2018. WHOI has major sub-awardees on the OOI Program Team to operate and maintain the marine infrastructure, manage the scientific data, and operate the cyberinfrastructure. The University of Washington (UW) operates the OOI Cabled Array. Oregon State University (OSU) operates the Coastal Endurance Array. WHOI operates the Pioneer Coastal Array as well as the Global Arrays at the three remaining OOI global sites in the Irminger Sea, the North Pacific and the

Sothern Ocean (the Argentine Basin Array was recovered without replacement in 2018), and also serves as the overall Program Management Office (PMO). Management of OOI data is now distributed between UW, OSU and WHOI. Rutgers University manages the cyberinfrastructure and 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 GEO manages OOI operations located within the Integrative Programs Section (IPS). The oversight, conducted through a coordinated effort between the IPS Section Head and the Ocean Sciences Section Head, includes the review of observatory metrics and data quality management, as well as integration of the OOI with any new science or infrastructure proposals and coordination with the science community. Additional NSF oversight of the OOI Program is provided by the Integrated Project Team whose core members include the Section Head for Integrative Programs and the Section Head for Ocean Science in OCE; and two members from within BFA from the Cooperative Support Branch and the Large Facilities Office.
- External Structure: The awardee has a Science Oversight Committee (SOC) which provides input and guidance internally to WHOI 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 to NSF regarding the operation and management of the OOI. The OOIFB is independent of the SOC and held several meetings during FY 2017 and FY 2018. The OOIFB also established a Subcommitttee focused specifically on the topics of Data Delivery and Cyberinfrastructure (DDCI) and developed a timeline for reviewing and assessing the performance of the data delivery system.
- Reviews: In December 2017, NSF conducted a review of the OOI Glider Operations Program component. In June 2018, NSF conducted an in-depth review of the readiness for transition with participation from both the COL OOI Team and the new WHOI OOI Team. In FY 2019, NSF will conduct a focused review of the DDCI and Community Engagement aspects of the OOI Program.

<u>Operations Costs</u>

Operations and management 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. Support for research using observatory data will be through the standard NSF proposal submission process to existing science programs in OCE; however, because the data are freely available over the internet, researchers around the world have access to the unique data sets OOI is producing regardless of the source of their support.

<u>Education and Outreach</u>

The OOI website and cyberinfrastructure provides an education portal to enable undergraduate level tools for education. The internal OOI SOC actively conducts outreach activities regarding the ocean science datasets to researchers, public, and education users.

Renewal/Recompetition/Termination

A successful NSF merit review of the proposal for the OOI facility took place in 2017 and 2018, and the new five-year OOI Operations and Management cooperative agreement with WHOI began on October 1, 2018. In preparation for the next recompetition in FY 2022, NSF will continue to conduct an annual Program Review and engage with the OOIFB to receive input from the Ocean Sciences community. In addition, NSF will hold a focused mid-award Program Review in 2021 of the performance of the awardee. The information from these activities will be used to determine whether to proceed with renewal or re-competition. The cooperative agreement with COL is operating under a No-Cost Extension through June 30, 2019 to support award closeout activities.

SEISMOLOGICAL FACILITY FOR THE ADVANCEMENT OF GEOSCIENCE (SAGE) **$23,160,000**
-$2,290,000 / -9.0%

Seismological Facility for the Advancement of GEosciences Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$25.45	-	$23.16	-$2.29	-9.0%

The Seismological Facility for the Advancement of GEoscience comprises 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 125 U.S. universities and non-profit institutions with research and teaching programs in seismology, 21 educational affiliates, three U.S. affiliates, and 128 foreign affiliates. SAGE was formed in late FY 2013 from the seismic components of the EarthScope facility and seismic facilities previously managed by IRIS. The FY 2020 Budget Request will enable SAGE to provide key services for the geoscience research community, including global and regional observing networks, field and technical support for experiments worldwide, data management and distribution systems, and other related activities.

Total Obligations for SAGE
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance	$25.45	-	$23.16	$17.89	$17.89	$17.89	$17.89	$17.89

[1] Outyear estimates are for planning purposes only.

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 of the Earth. To serve the research needs of the broad Earth science community, SAGE is organized under three primary service areas:

<u>Instrumentation Services</u>

- The Global Seismographic Network (GSN) consists of over 150 permanently-installed broadband digital seismic stations, most of which have real-time data access. GSN stations provide critical data for a range of global Earth science research and support key national security needs such as nuclear test-ban treaty verification and natural hazards warning and response. 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 to study a wide range of Earth processes.
- Polar Support Services 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. After operating 1,700 stations in the lower 48 states between 2004 and 2015, the full 280-station TA network

is now deployed in Alaska and western Canada. The TA stations collect data for use in studies of natural hazards including earthquakes, volcanoes, and tsunami; the plate tectonic process that have formed Alaska; Earth's magnetic field; and Earth's changing climate. NSF is currently working with other Federal agencies on a plan for adoption of stations for long-term operations and maintenance, and any stations that are not adopted will be decommissioned in FY 2020 and FY 2021.

- The Magnetotelluric 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.

<u>Data Services</u>
SAGE Data Services (DS) manages an archive of over 500 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 2018, more than 20,000 unique users downloaded over 134 terabytes of data from the SAGE archive. These data enable the wide range of Earth science studies described above.

<u>Education and Public Outreach</u>
The SAGE Education and Public Outreach program enables audiences beyond seismologists to access and use seismological data and research, including student internships, and programs for under-resourced educational institutions.

<u>Special Emphasis Areas</u>
The capabilities that SAGE provides have extensive societal impacts and supplement existing hazard monitoring efforts by US state and federal agencies. SAGE would provide key seismic-related infrastructure support to the United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA). The SAGE Global Seismographic Network is co-funded with support from the USGS and enables earthquake and tsunami hazard warning and monitoring by USGS and NOAA while also supporting the International Monitoring System that informs the Comprehensive Nuclear Test Ban Treaty Organization. SAGE instrumentation also aids in USGS volcano hazard studies. The magnetotelluric studies enabled by SAGE, which measure electromagnetic fields in the Earth, are being used to mitigate damage to the US power grid associated with potential space weather events.

The SAGE facility is used by researchers supported by programs in the Division of Earth Sciences and other divisions in the Directorate of Geosciences; including Geophysics, Tectonics, Frontier Research in Earth Sciences, GeoPRISMS, Marine Geology and Geophysics Programs, and the Earth Sciences Program and the Glaciology Program in the Antarctic Sciences Section of OPP. For NSF sponsored research, SAGE supports deployment of portable seismic instruments and use of data managed by DS to solve major Earth science problems.

Management and Oversight

- NSF Structure: EAR in GEO, through its Instrumentation & Facilities program, 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. In addition, an integrated project team consisting of representatives from EAR, BFA Division of Acquisition and Cooperative Support, and BFA Large Facilities Office work with cognizant program officer in addressing challenges and identifying potential barriers for success. The EAR Division

Director and Integrated Activities Section Head provide other internal oversight.

- External Structure: SAGE is managed and operated by IRIS, which is incorporated as a non-profit consortium representing 125 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: NSF recently completed a review of the SAGE facility which found that SAGE was a critical facility for U.S. and international Earth sciences. In FY 2019 EAR will conduct a joint review of the data services activities of SAGE and its geodetic facility counterpart Geodetic Facility for the Advancement of GEoscience (GAGE).

Renewal/Recompetition/Termination

A successful NSF merit review of the proposal for the SAGE facility took place in 2017 and 2018, and funding for the current SAGE cooperative agreement began in FY 2019 and will end in FY 2023. In preparation for the next recompetition that would begin in FY 2022, NSF will be engaging in two activities. First, NSF has requested the National Academy of Science, Engineering, and Medicine, through the decadal study "*Catalyzing Opportunities for Research in Earth Sciences*"[1], to explore different models to manage geophysical capabilities needed by the Earth Sciences community. Second, NSF will convene an interagency working group to identify the needs other agencies have for the capabilities currently provided by SAGE and GAGE. The information from these two activities will be used to draft the solicitation requesting proposals to support geophysical capabilities for EAR funded research and education.

[1] www8.nationalacademies.org/pa/projectview.aspx?key=51287

FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCS)

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR) $99,700,000
-$26,640,000 / -21.1%

National Center for Atmospheric Research Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$126.34	-	$99.70	-$26.64	-21.1%

[1] FY 2018 Actual includes $26.64 million in additional FY 2018 one-time funding above the requested amount.

NCAR is an NSF-sponsored FFRDC serving a broad research community, including atmospheric and geospace scientists and researchers in complementary areas of the environmental sciences and geosciences. Based in Boulder, Colorado, 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 117 degree-granting academic institutions.

As of September 2018, NCAR supported a total of 700.0 full time equivalents (FTEs), of which, 316.7 are funded under the NSF primary award to UCAR.

Number of FTEs Supported at NCAR

FTEs	Primary Award[1]	All Funding
Career Scientists	70.7	96.7
Scientific Support[2]	214.5	480.5
Other Staff [3]	31.5	122.8
Total	**316.7**	**700.0**

[1] The primary award supports substantial facility infrastructure that does not include staff costs.
[2] Scientific Support includes Associate Scientists, Project Scientists, Postdocs, Software Engineers, Engineers,
[3] Other Staff includes Administrative positions, Managers, Paid Visitors, Pilots and Mechanics.

NCAR provides world-class research programs, services, 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, an atmospheric sounder, and other surface sensing systems. NCAR staff work in close partnership with academic and other researchers. In 2018, 90 percent of NCAR's 805 peer-reviewed publications were published in collaboration with authors at other institutions, and NCAR hosted academic visitors from 333 different institutions. NCAR provided support in field campaigns that included staff from a total of 40 institutions.

Total Obligations for NCAR
(Dollars in Millions)

	FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[2] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Aircraft Support	$10.07	-	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Computational Infrastructure	32.38	-	32.50	32.50	32.50	32.50	32.50	32.50
Other Facility Support	26.55	-	26.50	26.50	26.50	26.50	26.50	26.50
Research & Education Support	30.70	-	30.70	30.70	30.70	30.70	30.70	30.70
Facility Upgrades	26.64	-	-	-	-	-	-	-
Total	**$126.34**	**-**	**$99.70**	**$99.70**	**$99.70**	**$99.70**	**$99.70**	**$99.70**

[1] FY 2018 Actual includes $26.64 million in additional FY 2018 one-time funding above the requested amount.
[2] Outyear estimates are for planning purposes only.

Facility Upgrades: In FY 2018, NSF awarded $26.64 million for essential upgrades to NCAR's facilities and programs. These one time funds supported critical maintenance at the NCAR Mesa Laboratory, major upgrades to the NCAR Research Aviation Facility, and a new Early Career faculty visitor's program.

Partnerships and Other Funding Sources: NCAR leverages NSF support with funding provided by other federal agencies and non-federal sources. In FY 2018, NCAR received approximately $38.34 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 $18.63 million from non-federal sources. This funding supports research collaboration that enhance NCAR's NSF-supported research goals or facilities missions.

Major Investments in FY 2020: In FY 2020, 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 processes on the surface of the Sun on space weather and weather on Earth. A continuous process of community prioritization will inform activities undertaken in FY 2020.

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 community-originated projects deemed by NSF, via separately-managed external peer review, to be of exceptional scientific merit, consistent with the research prioritization mentioned above.

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 and has over 1,700 unique users. These include the Community Earth System Model (CESM), the Weather Research and Forecasting Models (WRF), and the Model for Prediction Across Scales (MPAS), 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 researchers in the U.S. and worldwide – for example in 2018, the cumulative number of registered WRF users exceeded 45,000, and was growing by an average of 4,400 per year. 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 specialized Doppler weather radars, lidar systems, 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 the interaction of the solar wind 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 focal 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.

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) within GEO and the Division of Acquisition and Cooperative Support (DACS) oversee 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 cooperative 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 that NCAR's strategic mission is implemented effectively and for the benefit of NCAR's stakeholders in the atmospheric and geospace sciences.

- 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 2020. In FY 2018, as part of the recompetition process (see below), NSF conducted an extensive review of UCAR's financial viability andaccounting systems. No significant issues were raised.
- 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 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 NCAR Mesa Laboratory, designed by architect I.M. Pei, in Boulder, CO. *Credit: UCAR.*

Renewal/Recompetition/Termination

The cooperative agreement for the management and operation of NCAR was recently recompeted. Following an extensive and robust proposal review process, a new award was made to UCAR. This award began on October 1st, 2018, and is for five years, extendable for a further five years subject to satisfactory performance. The decision on whether to extend the award will be based upon the outcome of a comprehensive review of NCAR's science programs and management.

NATIONAL OPTICAL ASTRONOMY OBSERVATORY (NOAO) $22,910,000

-$3,850,000 / -14.4%

National Optical Astronomy Observatory Funding
(Dollars in Millions)

FY 2018 Actual[1]	FY 2019 (TBD)	FY 2020 Request	Change Over FY 2017 Actual Amount	Change Over FY 2017 Actual Percent
$26.76	-	$22.91	-$3.85	-14.4%

[1] The FY 2018 Actual includes $7.08 million in additional one-time FY 2018 funding above the requested amount.

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. 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 2018, NOAO employed 300 personnel in Arizona and Chile, including 45 support scientists and 10 postdoctoral fellows.

Total Obligations for NOAO

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
NOAO Base O&M (AST)	$20.31	-	$19.70	$20.29	$20.90	$21.56	$22.24	$22.94
Tucson Operations[2]	*10.76*	-	*9.58*	*9.87*	*10.16*	*10.47*	*10.78*	*11.11*
Chilean Operations	*8.49*	-	*9.00*	*9.27*	*9.55*	*9.86*	*10.20*	*10.54*
Kitt Peak Operations	*1.06*	-	*1.12*	*1.15*	*1.19*	*1.23*	*1.26*	*1.30*
Special Projects (AST)[2]	3.78	-	3.21	1.00	1.00	1.00	1.00	1.00
Special Projects (OMA)[2]	1.66	-	-	-	-	-	-	-
Facility Upgrades[2]	1.00	-	-	-	-	-	-	-
Total	**$26.76**	**-**	**$22.91**	**$21.29**	**$21.90**	**$22.56**	**$23.24**	**$23.94**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2020.

[2] The FY 2018 Actual includes additional one-time FY 2018 funding above the requested amount: $1.76 million under Tuscon Operations; $4.32 million under Special Project support; and $1.0 million under Facility Upgrades.

<u>Additional one-time FY 2018 Funding, $7.08 million</u>: FY 2018 included one-time support for the following activities:

- $1.76 million under Tucson Operations to support development of user data tools and the U.S. Extremely Large Telescope initiative;
- $4.32 million under Special Projects for upgrades ($1.0 million) of the Mayall 4-m Telescope on Kitt Peak in preparation for DOE dark energy observations and $3.32 million for the Astronomy Outreach Center at Kitt Peak, consisting of $1.66 million each from the MPS Division of Astronomical Sciences (AST) and the MPS Office of Multidisciplinary Activities (OMA); and
- $1.0 million for facilities upgrades on Kitt Peak and Cerro Tololo, primarily for road refurbishment.

<u>Partnerships and Other Funding Sources</u>: The managing organization for NOAO is the Association of Universities for Research in Astronomy, Inc. (AURA), which is comprised of 46 U.S. member institutions and four international affiliate members.

In a key NOAO partnership with the Department of Energy (DOE), a major imaging survey of approximately one-quarter of the southern sky was recently completed (February 2019) using the purpose-built Dark Energy Camera on the CTIO 4-meter Blanco telescope. Over the past six years more than 400 scientists from over 25 institutions have collected a rich trove of data–50 terabytes worth, mapping nearly a billion galaxies. The survey's primary goal is to probe the nature of dark energy and, although the survey is ending, both the camera used and the survey data themselves are expected to continue to yield abundant new discoveries.

Another related partnership with DOE involves installation of the Dark Energy Spectroscopic Instrument on the Mayall telescope on Kitt Peak in February 2018 for a five-year dark energy science program. In FY 2019, DOE assumed full operations funding of the Mayall Telescope.

NOAO is also a partner in the 4.1-meter SOuthern Astrophysical Research (SOAR) telescope at CTIO. SOAR partners include the University of North Carolina, Chapel Hill; Michigan State University; and the Ministério da Ciência, Tecnologia, Inovações e Comunições do Brasil.

A large number of universities and institutions (mostly from the U.S.) support their own astronomical facilities at KPNO and CTIO with services provided by NOAO and access to NOAO maintained infrastructure in exchange for payment of the facility's share of site and operations costs. 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 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.

<u>Education and Public Outreach</u>: 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 Undergraduates program. NOAO has a diverse education program, visitor centers, and a web-based information portal.[1]

<u>NOAO Base Operations and Maintenance, $19.70 million</u>:
- Tucson Operations: $9.58 million: This covers the cost for headquarters, offices, laboratories, and workshops in Tucson, Arizona. The FY 2018 Actual included special support for development of user data tools.
- Chilean Operations: $9.0 million: This supports the administration office and labs in La Serena, Chile and mountain operations on Cerro Tololo and Cerro Pachón.
- Kitt Peak Operations: $1.12 million: This funds basic infrastructure for all facilities on the mountain which are accounted as tenants.

<u>Special Projects, $3.21 million:</u>
- In FY 2020 Special Projects includes $1.21 million for continuing operational support of the NASA-NSF cooperative exoplanet observing program on the WIYN 3.5-m telescope on Kitt Peak.
- Special Projects also includes $2.0 million to support transition planning for a new National Center for Optical-Infrared Astronomy. With NSF guidance, AURA is currently developing a detailed plan that would fold NOAO, Gemini, and LSST operations into a single administrative element through the scope of the NOAO Federally Funded Research and Development Center. If implemented, the resulting organization would provide a modern management structure for U.S. optical-infrared nighttime telescope assets without reducing commitments to flagship facilities or national/international partnerships.

Management and Oversight
- NSF Structure: An NSF program officer in AST provides continuing oversight, including consultation with an NSF panel of external program 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. To address issues as they arise, AST has a dedicated Integrated Project Team which includes representatives from other NSF offices, such as the Office of General Counsel, OISE, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.
- 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

[1] www.noao.edu

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 at the midpoint of all cooperative agreements, NSF conducts both periodic and ad hoc external reviews of AURA management. A comprehensive review of AURA's performance is planned for FY 2019, the fourth year of the five-year cooperative agreement.

Renewal/Recompetition/Termination

The last competition for management and operation of NOAO was completed with the issuance of a new cooperative agreement with AURA starting October 2015 and ending September 2020. Following September 2020 and depending on the outcome of the FY 2019 review mentioned above, this cooperative agreement may be extended, re-competed, or re-cast as a new cooperative agreement for a National Center for Optical-Infrared Astronomy, described earlier.

NATIONAL RADIO ASTRONOMY OBSERVATORY (NRAO) **$85,660,000**
+$2,650,000 / 3.2%

National Radio Astronomy Observatory Funding[1]
(Dollars in Millions)

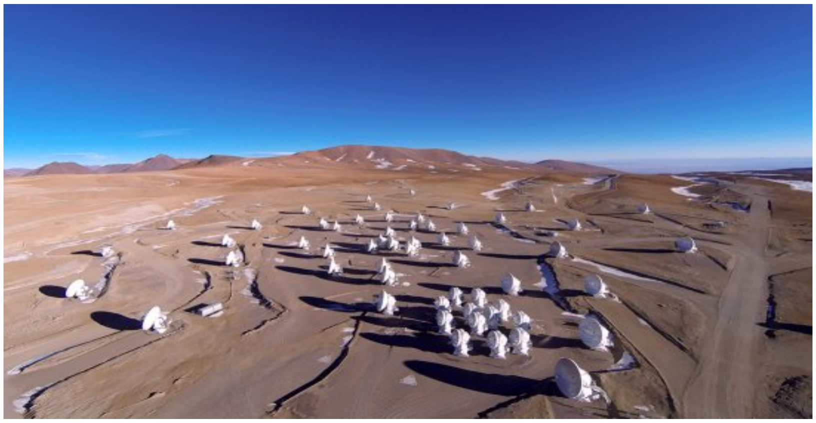
FY 2018 Actual[2]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
$83.01	-	$85.66	$2.65	3.2%

[1] This table aggregates funding requested for NRAO and ALMA base operations. FY 2020 also includes funding for the Very Long Baseline Array (VLBA).
[2] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount and $2.0 million in supplemental appropriation funding for hurricane repairs.

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, x-ray, and gravitational wave 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 the sources of 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; the Very Long Baseline Array (VLBA), with 10 sites throughout the continental United States, Hawaii, and the U.S. Virgin Islands; 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. In addition to conducting NSF-funded astrophysical observations, the VLBA is used for fundamental support of the International Celestial Reference Frame, under an agreement with the United States Naval Observatory (USNO). NRAO facilities annually serve over 2,500 users worldwide; moreover, continued high 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 2020 will consist of 402 full-time equivalent positions (FTEs) in the operations and maintenance components, including: 71 in telescope operations, 47 in science support and research, 39 in development programs, 81 in computing and data management, 73 in administrative services, and 19 in education and public outreach. These numbers exclude staff at the partitioned Green Bank Observatory, managed and operated separately from NRAO, as well as 72 staff in the NRAO common cost pool that serve multiple observatories. In addition, the NRAO managing organization, Associated Universities, Inc. (AUI), employs local ALMA operations staff in Chile, currently about 250 FTEs.



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.*

In September 2017, Hurricane Maria damaged the VLBA facility on St. Croix, Virgin Islands. Funding for observatory repairs was provided in the Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) totaling $16.30 million. Of the total amount provided, $2.0 million was identified for NRAO and obligated in FY 2018.

Total Obligations for NRAO

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance[2]	$38.96	-	$38.40	$39.45	$40.53	$41.65	$39.79	$40.98
Telescope Operations	*10.98*	-	*10.99*	*11.28*	*11.60*	*11.91*	*11.38*	*11.72*
Development	*9.70*	-	*7.57*	*7.77*	*7.98*	*8.21*	*7.84*	*8.07*
Science Operations	*5.91*	-	*6.17*	*6.35*	*6.53*	*6.71*	*6.41*	*6.60*
Administrative Services	*9.46*	-	*10.49*	*10.77*	*11.06*	*11.37*	*10.86*	*11.19*
Directors Office	*2.16*	-	*2.42*	*2.49*	*2.55*	*2.62*	*2.51*	*2.58*
Education and Public Outreach	*0.75*	-	*0.76*	*0.79*	*0.81*	*0.83*	*0.80*	*0.82*
ALMA Operations	38.55	-	47.26	48.68	50.14	51.64	56.19	57.79
Facility Upgrades[3]	3.50	-	-	-	-	-	-	-
Hurricane-related Repairs[4]	2.00	-	-	-	-	-	-	-
Total	**$83.01**	**-**	**$85.66**	**$88.13**	**$90.67**	**$93.29**	**$95.98**	**$98.77**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2026.

[2] FY 2018 funding for VLBA, formerly the Long Baseline Observatory (LBO), was provided under a separate cooperative agreement and is shown in the Other AST Facilities narrative. Beginning October 1, 2018, operations funding for LBO was reintegrated into NRAO as the VLBA at $3.43 million per year.

[3] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount.

[4] Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) provided NSF $16.30 million in no-year funding to repair radio observatory facilities damaged by hurricanes that occurred during 2017. Of the total amount provided, $2.0 million of the total amount was identified for NRAO and obligated in FY 2018.

Facility Upgrades: In FY 2018, NSF awarded $3.50 million for repair of tracks at the VLA (supporting critical maintenance) and for the provision of fiber optics for the VLBA, enhancing that facility's data transmission capability.

The total FY 2020 NRAO Budget Request includes ALMA operations ($47.26 million) and non-ALMA operations and maintenance ($38.40 million). Included in the non-ALMA funding is $3.43 million for the VLBA which was reintegrated into NRAO beginning October 1, 2018. FY 2018 funding for the VLBA, formerly Long Baseline Observatory (LBO), was provided under a separate cooperative agreement and is shown in the Other AST Facilities narrative.

Partnerships and Other Funding Sources: NRAO supplements NSF Division of Astronomical Sciences (AST) support with funding provided by other NSF sources, other federal agencies, and non-federal sources. In FY 2018, NRAO received approximately $100,000 from non-AST sources at NSF, $1.20 million from other federal agencies, and $1.50 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. The LBO received $6.76 million from the USNO while it was part of Other AST Facilities, before it was reintegrated into NRAO at the beginning of FY 2019. For FY 2019, USNO provided $4.14 million in funding for the VLBA, and plans to provide $4.19 million for FY 2020.

Telescope Operations, $10.99 million: This encompasses support for direct telescope and array operations of the VLA including maintenance, infrastructure upgrades, and telescope management.

Development, $7.57 million: The FY 2020 Budget Request continues to support development programs including next generation electronics and detectors for radio astronomy, as well as planning and the development of technologies for a next-generation centimeter wavelength facility (next generation Very Large Array, or ngVLA).

Science Operations, $6.17 million: This includes telescope time allocation, staff research, science training and education, and science community outreach.

Administrative Services, $10.49 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, $2.42 million: This supports the director’s office and managing organization costs.

Education and Public Outreach, $760,000: NRAO supports a comprehensive outreach program that makes radio astronomy information available to the public.[24] With over 150 students involved per year, NRAO facilities are used by graduate students carrying out dissertation research and work experience programs and by undergraduates participating in the Research Experiences for Undergraduates 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, $47.26 million: In FY 2015, NRAO completed construction of the international ALMA Observatory, funded through the MREFC account. Early operations funding for ALMA began in FY 2005 and ramped 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, an 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. This program officer participates in the international ALMA Board and attends AUI/NRAO governance and advisory

[24] https://public.nrao.edu/

committee meetings. To address issues as they arise, AST has a dedicated Integrated Project Team (IPT) which includes representatives from other NSF offices, such as the Office of General Counsel, OISE, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.

- External Structure: Management is through a cooperative agreement with AUI, which manages the observatory through its own community-based oversight and users committees. The NRAO director reports to the AUI president. 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 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.

Renewal/Recompetition/Termination

Following a solicitation issued in FY 2014 (NSF 14-568), management and operation of NRAO, including ALMA, was competed and the NSB authorized a cooperative agreement with AUI for October 2016 through September 2026. Reintegration of the VLBA operations support into NRAO occurred in October 2018.

NATIONAL SOLAR OBSERVATORY (NSO) $21,140,000
-$9,680,000 / -31.4%

National Solar Observatory Funding

(Dollars in Millions)

FY 2018[1] Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Request Amount	Percent
$30.82	-	$21.14	-$9.68	-31.4%

[1] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount as well as $8.0 million to forward fund part of the FY 2019 operations costs.

FY 2020 reflects the equilibrium level of the NSO budget commensurate with requirements to operate the Daniel K. Inouye Solar Telescope (DKIST), the construction of which is scheduled to be completed in June 2020. (See the MREFC chapter for more information). The FY 2020 Budget Request fully funds both the DKIST operations requirement (science operations and data center) and the NSO Integrated Synoptic Program (NISP).

As a Federally Funded Research and Development Center, NSO is headquartered on the campus of the University of Colorado, Boulder and provides leadership to the solar community through management of the construction of DKIST. When completed, DKIST will be the world's most powerful solar observatory. Life on Earth is critically dependent upon the Sun. Solar phenomena such as space weather (e.g. geomagnetic storms) can significantly impact our increasingly technological society. DKIST will investigate the structure and evolution of magnetic structures on the Sun on spatial scales of tens of kilometers, the fundamental length scales of the processes that drive space weather. With DKIST poised to answer fundamental questions in solar physics by providing transformative improvements over current ground-based facilities, solar research enabled by DKIST will benefit all of humankind. NSO also operates a coordinated worldwide network of six telescopes specifically designed to study solar oscillations. NSO routinely provides 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.

In 2010, the National Academies of Science, Engineering, and Medicine (the National Academies) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*,[1] the National Academies 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 MPS Division of Astronomical Sciences (AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*,[2] 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

[1] www.nap.edu/catalog.php?record_id=12951
[2] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

recommended continued operation of the Dunn Solar Telescope (DST) at Sacramento Peak through 2017 and a 50.0 percent reduction in funding of NISP. The status of the transition of NSO-operated facilities is as follows:

- *McMath-Pierce Solar Telescope, Kitt Peak, AZ*: NSO ceased operating the McMath-Pierce Solar Telescope as a national user facility at the end of FY 2017. NSF completed a divestment options study of NSO facilities on Kitt Peak and initiated an environmental impact analysis process in FY 2018, consistent with the National Environmental Policy Act. In late FY 2018, NSF made a five-year award to the Kitt Peak National Observatory Visitor Center, part of NSF's National Optical Astronomy Observatory, to repurpose the McMath-Pierce facility as an astronomy outreach and education center. This Windows on the Universe Center for Astronomy Outreach will highlight all of NSF's research facilities related to astronomy and astrophysics.
- *Sacramento Peak Observatory, Sunspot, NM*: This facility includes the DST and associated infrastructure including office space, laboratory space, dining facilities, and housing. NSO ceased operating Sacramento Peak Observatory as a national user facility at the end of FY 2017. 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. As discussions on the future of Sacramento Peak continued with NMSU, in parallel NSF began the preparation of an Environmental Impact Statement (EIS) in late 2016. Fully compliant with the National Environmental Policy Act, the final EIS was published in November 2018. The NSB gave its approval for the NSF Director (or her designee), at her discretion, to sign the Record of Decision (ROD) selecting Alternative 2: *Transition to Partial Operations by Interested Parties with Reduced NSF Funding*. Moving forward, a potential plan that would be consistent with Alternative 2 involves an NSF-NSO-NMSU partnership to operate the facility in a limited fashion. The ROD was signed in February 2019.
- *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 five-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. (Also see Partnerships section below). NSO is in the process of relocating the SOLIS facility to the Big Bear Solar Observatory (BBSO) on Big Bear Lake, CA.

Total Obligations for NSO

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
NSO Base Operations	$5.06	-	$3.83	$3.94	$4.06	$4.19	$4.31	$4.31
NSO Education & Public Outreach	0.26	-	0.30	0.31	0.32	0.33	0.34	0.34
DKIST Operations[2]	22.00	-	17.01	17.54	18.08	19.13	19.71	20.30
Facility Upgrades[3]	3.50	-	-	-	-	-	-	-
Total	**$30.82**	**-**	**$21.14**	**$21.79**	**$22.46**	**$23.65**	**$24.36**	**$24.95**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends September 2024.

[2] Excludes funding for cultural mitigation activities in FY 2018 and FY 2020 as agreed to during the compliance process. The FY 2018 Actual includes $8.0 million to forward fund FY 2019 operations. See the MREFC chapter for more information on DKIST.

[3] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount.

<u>Facility Upgrades</u>: In FY 2018, NSF awarded $3.50 million for development of DKIST level 2 (advanced) data products, making DKIST data more accessible and usable to the solar research community.

Partnerships and Other Funding Sources: The managing organization for NSO is the Association of Universities for Research in Astronomy, Inc. (AURA), which comprises 46 U.S. member institutions and four international affiliate members. NSO partners include NOAA, the National Aeronautics and Space Administration, industrial entities, and universities and institutes that collaborate with NSO on solar instrumentation development. NSF is currently under discussions with New Mexico State University (NMSU) regarding future operations of Sacramento Peak Observatory and New Jersey Institute of Technology on future operations of SOLIS at BBSO.

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. 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. NSO is continuing the process of upgrading the GONG facility with $2.50 million of funding provided in FY 2016, with the upgrade expected to be completed in FY 2019. NSF and NOAA are currently in the fourth year of a five-year interagency agreement whereby NOAA provides approximately $800,000 per year in funding support for GONG operations.

NSO Base Operations, $3.83 million: NSO Base Operations includes the offices at NSO's Boulder, Colorado headquarters and the world-wide NSO Integrated Synoptic Program consisting of the GONG array and the SOLIS telescope.

DKIST Operations, $17.01 million: Support for DKIST operations is through the R&RA account, while DKIST construction support is through the MREFC account. (See the MREFC chapter for more information on construction.) The FY 2020 Budget Request for DKIST Operations represents the equilibrium level for the NSO budget commensurate with requirements to operate DKIST. This profile is funding the development of the DKIST science operations and data center in preparation for full DKIST operations, which is expected to begin in 2020.

Education and Public Outreach, $300,000: 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 program. NSO has diverse education programs, including teacher training and curriculum development, and a newly-redesigned web portal.[3]

Management and Oversight

- NSF Structure: NSF oversight is handled by a program officer in AST working cooperatively with staff from MPS, BFA, the Office of the General Counsel, and the Office of Legislative and Public Affairs. Within BFA, the Large Facilities Office provides advice to program staff and assists with agency oversight and assurance. Representatives from some the above NSF offices comprise the recently-chartered NSO Integrated Program Team, which meets on a semi-annual basis to discuss outstanding program issues. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight.
- 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 utilizes a users committee for the purposes of self-evaluation and

[3] www.nso.edu

prioritization. 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.

Reviews:

- NSF conducts regular reviews of NSO's Annual Progress Report and Program Plan (APRPP). The most recent APRPP review was held in February 2018 with the next scheduled review to occur March 2019.
- NSF periodically conducts Business Systems Reviews covering both the managing organization, AURA, and the center, NSO. The most recent BSR ended in March 2016, and AURA successfully implemented report recommendations and resolved outstanding issues.
- In Q3 FY 2019 a comprehensive midterm review of NSO's long-range plan for the second five years of the cooperative support agreement (CSA) will be conducted. Results of this review will be reported to the NSB.
- NSO also participates in reviews of the DKIST project. Recent reviews include: an Independent Risk Assessment conducted by the NSF Large Facilities Office (September–December 2017), a GAO assessment of "NSF Major Projects" (November 2017–June 2018), and an incurred cost audit (August 2018–present). In addition, a comprehensive external programmatic review and an Earned Value Management (EVM) system surveillance are planned for early Q3 FY 2019. These DKIST related reviews are described in the DKIST narrative in the MREFC chapter.

Renewal/Recompetition/Termination

In August 2014, the NSB authorized a renewed cooperative agreement with AURA for management and operation of NSO. The renewal award was put into place in June 2015 and will run through September 2024.

OTHER ASTRONOMICAL FACILITIES

$8,420,000
-$3,490,000 / -29.3%

Other Astronomical Facilities Funding
(Dollars in Millions)

FY 2018[1] Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$11.91	-	$8.42	-$3.49	-29.3%

[1] FY 2018 Actual includes both GBO and LBO/VLBA, while the FY 2020 Request only includes GBO funding.

For FY 2020, Other Astronomical Facilities consists of the Green Bank Observatory (GBO), which was separated from the National Radio Astronomy Observatory (NRAO) beginning in FY 2017. The Long Baseline Observatory (LBO), which was separated from NRAO at the same time as GBO and was previously in "Other Astronomical Facilities," has been reintegrated as the Very Long Baseline Array (VLBA) into NRAO effective October 1, 2018. The reassignment of that share of the funding request accounts for the significant difference in the requested FY 2020 total. Associated Universities, Inc. (AUI) remains the managing organization for GBO through a cooperative agreement with NSF. This narrative presents the FY 2020 Budget Request for GBO.

GBO provides ground-based radio-wavelength research facilities for the U.S. national community, while carrying out a program in education for public visitors and students. The Green Bank Telescope (GBT) is the world's largest fully steerable single-dish radio telescope and is GBO's flagship research instrument. The GBO contributes to a broad area of scientific research, including fundamental physics, astronomy, and the search for intelligent life beyond the Earth. GBO is the administrative site of the 13,000-square-mile National Radio Quiet Zone, where all radio transmissions are limited. Having telescopes within this quiet zone allows for detection of faint scientific signals that would otherwise be drowned out by human-made signals.

In 2010, the National Academies of Science, Engineering, and Medicine conducted their sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*,[1] the 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 MPS Division of Astronomical Sciences (AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*,[2] was released in August 2012 and included recommendations about all major AST telescope facilities.

In 2012, the Portfolio Review Committee recommended divestment of GBT and VLBA from AST funding because of a less compelling mapping to the science questions of the 2010 decadal survey compared to other facilities. As announced in a Dear Colleague Letter, NSF 13-074,[3] 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/LBO. Existing partnerships are described below, and additional partner

[1] www.nap.edu/catalog.php?record_id=12951
[2] www.nsf.gov/mps/ast/ast_portfolio_review.jsp
[3] www.nsf.gov/pubs/2013/nsf13074/nsf13074.jsp

discussions with governmental and non-governmental entities are ongoing.

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 obligations for GBO and VLBA/LBO were heavily matrixed and not separable from the overall obligation for NRAO. Hence, GBO and VLBA/LBO, which were previously included in the NRAO narrative, were first presented as a separate entry in the FY 2017 Budget Request. Through the development of (primarily) federal government partnerships, NSF was able to decrease its funding commitment to VLBA/LBO operations to a satisfactory level that ensures the future of the facility and enabled the reintegration back into NRAO at the beginning of FY 2019 while maintaining the overall facility top-level funding line.

Pursuant to the National Environmental Policy Act, NSF has conducted a formal environmental review of GBO and developed an Environmental Impact Statement (EIS), which considers the environmental impact of various future alternatives for GBO. The final EIS was published in February 2019, and the process is anticipated to conclude in FY 2019 with a decision on the way forward for GBO, which will be memorialized in a Record of Decision published by NSF.

Total Obligations for Other Astronomical Facilities

(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
GBO Operations & Maintenance	$8.42	-	$8.42	$8.42	$8.42	$8.42	$8.42	$8.42
LBO Operations & Maintenance[2]	3.49	-	-	-	-	-	-	-
Total	**$11.91**	**-**	**$8.42**	**$8.42**	**$8.42**	**$8.42**	**$8.42**	**$8.42**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement for GBO has been extended through September 2019.

[2] Funding for LBO was reintegrated into NRAO as VLBA effective October 1, 2018.

GBO Operations and Maintenance: The FY 2020 Request of $8.42 million encompasses support for direct telescope operations at GBO, including maintenance, infrastructure upgrades, and telescope management, as well as funds allocated for Education and Public Outreach.

Partnerships and Other Funding Sources: In FY 2017, GBO received approximately $4.3 million from other sources, mostly from non-federal partners. External (non-NSF) contributions represented approximately 35 percent of the total operations budget of GBO. Many of the GBO partnerships involve guaranteed allocations of observing time on the GBT.

In FY 2016, GBO began a 10-year partnership with Breakthrough Listen and 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 2020. (The NANOGrav funding comes from the NSF award to the NANOGrav Physics Frontiers Center.) In addition, the GBO partnership with the RadioAstron space mission continued into FY 2019. Other partnership development efforts are continuing.

Management and Oversight

- NSF Structure: In consultation with community representatives, a dedicated AST program officer carries out continuing oversight and assessment for GBO 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 has a dedicated Integrated Project Team for GBO, which includes representatives from other NSF offices, such as the Office of General Counsel, OISE, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities (CORF), also provide high-level guidance, support, and oversight.

- 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 director reports directly to the AUI Vice President for Radio Astronomy.
- Reviews: NSF conducts annual reviews of the Program Operating Plan and reports, including external advice from community representatives. The last annual review took place in June 2018, and the next one is scheduled for April 2019.

Renewal/Recompetition/Termination

GBO is currently supported through a cooperative agreement, which ends on September 30, 2019. NSF expects to receive a proposal from AUI that will help to identify the future structure and operational support required for GBO beyond FY 2019.

OTHER FACILITIES FUNDING

Major Research Equipment and Facilities Construction Account Projects

The MREFC account supports the acquisition, construction, and commissioning of major facilities and larger mid-scale research infrastructure 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 and infrastructure are provided through the Research and Related Activities (R&RA) 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

NSF Big Ideas – Convergence Accelerator:

NSF Research Big Ideas:

NSF Enabling Big Ideas:

Ongoing Major FY 2020 Investments:

STEM Education and Workforce:

Other NSF-Wide Activities:

National Science and Technology Council (NSTC) Activities:

NSF CONVERGENCE ACCELERATOR (NSF C-ACCEL)

NSF C-Accel Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
NSF-Funded Activities	-	-	$60.00
IA	-	-	*60.00*
Partnership-Funded Activities	-	-	40.00
Total	**-**	**-**	**$100.00**

Overview

NSF C-Accel seeks to transform how NSF supports the most innovative science, reflecting its commitment to be at the cutting-edge, supporting foundational research, while also encouraging rapid advances through partnerships between academic and non-academic stakeholders. NSF C-Accel is an entity that will make timely investments that (1) initiate new capabilities to accelerate convergence research in areas of national importance, and (2) build capacity in multi-stakeholder convergence teams to address these critical challenges. Focusing on use-inspired, convergence research, with directed deliverables and using an approach that rewards innovation, risk-taking, and transition to use, NSF C-Accel is modeled on acceleration and innovation activities that have proven successful at the most forward-looking universities and companies.

NSF C-Accel will align NSF's processes and operations with contemporary science and engineering research. As the only federal agency that funds foundational research and education across all fields of non-biomedical science and engineering, NSF is uniquely poised to initiate this structural change. NSF also has a unique role with colleges and universities, which are critical participants in this activity, as well as with other stakeholders, such as other federal agencies, industry, non-profits, foundations, and funding agencies around the world. While NSF C-Accel is separate from directorates in leadership, budget, and programmatic approaches, it will be aligned with, build upon, and stimulate new directions for directorates' foundational research investments. These activities will become a standard part of NSF's portfolio of funding mechanisms to accelerate research across a broad range of themes.

To build partnerships, NSF C-Accel will use a variety of methods, such as multi-stakeholder roundtables and workshops, to surface grand challenge themes that are of mutual interest and that could benefit from acceleration. Individual themes are anticipated to last up to five years with the option to continue another five years, if deemed successful. Each theme will engage a number of multi-stakeholder teams that will work collaboratively to accelerate science and engineering and the transition from research to practice.

An initial NSF C-Accel pilot in FY 2019 focuses on two of NSF's research Big Ideas: HDR and FW-HTF. Themes (or tracks) that come from these particular research areas have been identified by the cross-agency NSF C-Accel Working Group and align with Administration R&D Priorities,[1] the President's Management Agenda,[2] and the U.S. Five-Year STEM Education Strategic Plan.[3] Pilot tracks include, for HDR, advancing data-driven discovery using artificial intelligence (AI) and machine learning, through early

[1] Office of Management and Budget's and Office of Science and Technology Policy's "FY 2020 Administration Research and Development Budget Priorities" memo (M-18-22), www.whitehouse.gov/wp-content/uploads/2018/07/M-18-22.pdf
[2] Office of Management and Budget (2018), www.whitehouse.gov/wp-content/uploads/2018/03/The-President%E2%80%99s-Management-Agenda.pdf
[3] Charting a Course for Success: America's Strategy for STEM Education" National Science and Technology Council (2018), www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf.

prototypes of an open knowledge network. The pilot tracks for FW-HTF include (1) smart job matching, including the development of predictive analytic tools, economic and labor market analyses of future workplace skill requirements, and educational technologies for life-long, adult learning; and (2) innovative approaches to support the development of workers with the skills required for 21st century work, including data science, predictive analytics and AI/machine learning techniques.

These initial NSF C-Accel tracks are distinguished from the corresponding Big Ideas by the nature of the research, the time scale of the activities supported, and the more hands-on, agile approach to project management and support that is envisioned.

Goals

1. Accelerate the progress of use-inspired convergence research.
    - Accelerate scientific discovery and innovation by applying more agile team identification, funding, and project management mechanisms to use-inspired, convergence research that requires the integration of knowledge, skills, and methodologies from multiple disciplines and stakeholders.
2. Harness partnerships to design and enable translational convergence research.
    - Assist academic researchers to engage with non-NSF partners – such as commercial entities, non-profits, foundations, philanthropies, other state or federal agencies, and international funders – to create partnerships that identify high-impact research directions and collaborate to achieve the research goals.
3. Focus cohorts of teams around broad national goals.
    - Support activities that bring together the range of expertise needed to tackle pressing, transdisciplinary research challenges and enable the formation of advanced research teams. Use coopetition mechanisms to enable cohorts of teams to progress towards research goals more rapidly than single teams alone can do.

FY 2020 Investments

In FY 2020, $60.0 million will support the continuation of the two initial tracks of the NSF C-Accel. This funding will also support new tracks stimulated by research in HDR, FW-HTF, and other Big Ideas, based on mutual interest of the partners and readiness of the research community to respond. New tracks will develop through community workshops, roundtables (e.g., with industry, non-profits, and foundations) and analysis of emerging foundational advances in NSF's 10 Big Ideas.

NSF anticipates that external partners will contribute an additional $40.0 million in FY 2020. For the partners, this is a new avenue for R&D, allowing access to academic researchers working at the forefront of knowledge. For the academic researchers, this allows access to partners who are interested in contributing to research projects and the broader themes/tracks.

HARNESSING THE DATA REVOLUTION FOR 21ST-CENTURY SCIENCE AND ENGINEERING (HDR)

HDR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (CISE)	**-**	**-**	**$30.00**
Foundational Activities	**$169.62**	**-**	**$117.24**
BIO	3.20	-	7.80
CISE	95.63	-	55.25
EHR	4.30	-	2.50
ENG	21.58	-	12.60
GEO	2.90	-	3.00
MPS	34.62	-	20.00
SBE	7.39	-	6.09
IA	-	-	10.00
Total	**$169.62**	**-**	**$147.24**

Overview

NSF's HDR Big Idea is a national-scale activity to enable new modes of data-driven discovery in science and engineering. Access to the next level of discovery relies on translating complex data from observations, experiments, and simulations into knowledge. To help close the loop from data generation to analysis, and on to simulation and finally discovery, the HDR Big Idea will support fundamental research in data science and engineering; development of a cohesive, federated approach to the research data infrastructure needed to power this revolution; and development of a 21st-century data-capable workforce. Individuals and communities will also benefit from data-rich capabilities, infrastructure, and services.

Goals

The HDR vision is realized through an interrelated set of goals:
1. The foundations of data science: Develop the theoretical foundations of data science and its applications through integrated research and training activities;
2. Algorithms and systems for data science: Support the development and use of novel algorithms and systems to support data science as well as data-driven science and engineering;
3. Data-intensive science and engineering: Stimulate advances in multiple areas of science and engineering through data-intensive research that harnesses diverse data sources and applies new methodologies, technologies, and infrastructure for data generation, collection, modeling, and analysis;
4. Data cyberinfrastructure: Foster the creation of a robust, trustworthy, and performant data cyberinfrastructure and services that can support data-driven research and discovery in multiple areas of science and engineering; and
5. Education and workforce development: Develop coordinated activities in data science education, researcher training, and knowledge transfer, and harness the power of data at the local, state, national, and international levels in the service of science and society.

Each of these goals is designed to amplify the intrinsically multidisciplinary nature of the emerging field of data science. The HDR Big Idea will establish theoretical, technical, and ethical frameworks that will be applied to tackle data-intensive problems in science and engineering, contributing to data-driven decision making that impacts society.

FY 2020 Stewardship Investments

Foundations of Data Science ($6.0 million)
HDR will continue to support research in data science and data-enabled science and engineering primarily through the Transdisciplinary Research In Principles Of Data Science (HDR TRIPODS) program. HDR TRIPODS will bring together the electrical engineering, mathematics, statistics, and theoretical computer science communities. Through integrated research and training activities, these communities will collaborate to develop the theoretical foundations of data science. Phase I HDR TRIPODS awards will support the development of small, collaborative "data science institutes." Subsequent Phase II awards will enable the most successful of these smaller institutes to expand in scope and impact into a smaller number of larger-sized data science institutes.

Data-Intensive Research in Science and Engineering ($21.0 million)
HDR will continue to support the Institutes for Data-Intensive Research in Science and Engineering (DIRSE). The DIRSE institutes will complement the HDR TRIPODS institutes described above, and will harness diverse data sources and develop new algorithms, methodologies, systems, technologies, and infrastructure for data management and analysis to address critical national problems. These institutes will be developed through a two-phase process involving conceptualization followed by convergence. By creating a portfolio of interrelated institutes, NSF aims to accelerate discovery and innovation in multiple areas of data-intensive science and engineering.

Education and Workforce Development ($3.0 million)
HDR will continue to support data science education and workforce development through its Data Science Corps program. This program will provide data scientists and data science students with practical experiences, new skills, and teaching opportunities across multiple learning environments. The program will also strive to promote data literacy and provide basic training in data science to the existing workforce across various communities.

Additional FY 2020 Investments

HDR Track within the NSF Convergence Accelerator (NSF C-Accel)
The NSF C-Accel seeks to transform how the agency supports the most innovative science, reflecting its commitment to be at the cutting-edge, supporting foundational research, while also encouraging rapid advances through partnerships between academic and non-academic stakeholders. Tracks within the NSF C-Accel focus on grand challenge themes that would benefit from acceleration. To fully exploit the progression from data to knowledge to information, the HDR track within the NSF C-Accel will support research and development of an Open Knowledge Network (OKN). The OKN will allow stored data (both structured and unstructured data) to be located, and their attributes and relationships to other data and to real-world objects and concepts to be understood at a semantic level. A focus of the OKN will be on exploiting publicly available datasets from the U.S. Government and other sources. For more information on the NSF C-Accel, please refer to the NSF C-Accel narrative in this chapter.

Foundational Activities
These activities comprise ongoing investments by NSF directorates and offices in programs that laid the initial foundations for the HDR Big Idea and HDR Track in the C-Accel. These activities will continue to be supported and aligned with the overall HDR strategic goals. These foundational programs are currently managed by NSF's directorates and offices and will continue to remain within the directorates and offices with respect to their funding and management.

THE FUTURE OF WORK AT THE HUMAN-TECHNOLOGY FRONTIER (FW-HTF)

FW-HTF Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (ENG)	**-**	**-**	**$30.00**
Foundational Activities	**$159.95**	**-**	**$114.30**
CISE	89.89	-	78.00
EHR	22.00	-	10.30
ENG	35.83	-	14.50
SBE	12.23	-	11.50
Total	**$159.95**	**-**	**$144.30**

Overview

The FW-HTF Big Idea supports convergent research to develop new human-technology partnerships leading to increased worker productivity and innovation. This research will prepare the workforce for human-technology partnerships by combining the benefits of new technologies, such as artificial intelligence (AI) and virtual environments, with increased understanding of value-based social, economic, and educational impacts.

The landscape of jobs and work is changing with unprecedented speed, driven by the development of new technologies that have moved from the factory floor to an expanding array of knowledge and service occupations. These changes, while promising benefits to the Nation in the creation of new industries and occupations, increased productivity, enhanced innovation, and sustained global leadership, come with risks for workers as technology may, in some cases, eliminate entire job classes.

The FW-HTF Big Idea, started in FY 2018, is responding to the challenges and opportunities associated with the changing landscape of jobs and work by supporting new convergent research to understand and advance the human-technology partnership, design new technologies to augment human performance, illuminate the emerging socio-technological landscape, and foster lifelong and pervasive learning with technology. Investments in research and development at the human-technology frontier will enable technologies that amplify and augment human capabilities to learn, adapt, make decisions, and make sense of complex patterns and situations. It will be necessary to fund interdisciplinary research at the intersection of computer and information science, engineering, social, behavioral, and economic sciences, and education. Increasing human capabilities is the result of the incorporation of advances in AI, data science, and closely related technologies for sensing, actuation, coordination, communication, and control with humans-in-the-loop; and depends upon understanding human communication, thinking, and action. These advances will underpin the creation of systems that are adaptive and human-centered and capable of collaborative interactions with humans. By evaluating the aspects of work that humans do most effectively and the complementary aspects of work that technology can improve, the research will support advances that improve work quality, increase worker productivity, and even make work more meaningful. Additionally, further research investments are needed to understand how these changes will affect society and what new approaches to education and training will be required. Moreover, NSF investments will explore the ethical and societal implications of new scientific technologies such as AI and advance the pursuit and adoption of responsible and ethical approaches to using data and furthering data science. These research investments will accelerate progress and enable the Nation's workforce and economy to lead in a future that is increasingly and unavoidably driven by technology and knowledge.

Goals

The FW-HTF Big Idea seeks to maximize benefits and minimize risks of the changing technological environment, to foster support of the workforce in increasing productivity and innovation, and to lay the foundation for new knowledge and developments in science and engineering, through the following four strategic goals:

1. *Understand and build the human-technology partnership*. Research on the future of work will identify how new technologies affect jobs, the workplace, organizations, and society, as well as how these technologies can be designed and built to increase national productivity, job opportunities, and worker satisfaction, while enabling worker creativity.
2. *Design and develop new technologies to augment human performance*. By augmenting the physical and mental capabilities of humans, new technology can open new job opportunities. Using AI-based, real-time, adaptive physical and cognitive prosthetics can increase opportunities for those with disabilities and enhance capabilities in all individuals.
3. *Illuminate the emerging socio-technological landscape*. As technology becomes increasingly more capable, companies and organizations will be transformed, as will society, the economy, and relevant laws. Research will clarify the benefits and risks of such change, and help support human value-based design of new technology and software.
4. *Foster lifelong and pervasive learning through technology*. Design of training, including novel AI-based approaches, will support both the skill training and reskilling needed to work with new technology and to enable workers to migrate from old jobs to new ones. Adaptive pervasive training systems will depend on new research in cyberlearning systems, as well as the integration of training into task performance and management.

FY 2020 Investments

FY 2020 activities will leverage the investments made through the FY 2018 and FY 2019 FW-HTF solicitations that support research on advancing cognitive and physical capabilities in the context of human-technology interactions, the evolving symbiosis of human and artificial intelligence in work, and the understanding and explanation of productivity, innovation, and learning in the workplace. New funding opportunities will be released in FY 2020 that continue to emphasize the four FW-HTF strategic goals listed above. FY 2020 catalytic activities include standard grants, workshops, and grants for planning and coordination. These funding opportunities—such as the planning grants and coordination grants—will set the foundation for future integrative activities such as centers-scale institutes and larger-scale grants in FY 2021 and beyond. During FY 2020, FW-HTF will also seek synergies with other Big Ideas and NSF-wide efforts, including GCR, HDR, Mid-scale RI, NSF INCLUDES, and NRT.

<u>The FW-HTF Track within the NSF Convergence Accelerator (NSF C-Accel)</u>

The NSF C-Accel seeks to transform how the agency supports the most innovative science, reflecting its commitment to be at the cutting-edge, supporting foundational research, while also encouraging rapid advances through partnerships between academic and non-academic stakeholders. Tracks within the NSF C-Accel focus on grand challenge themes that would benefit from acceleration. The FW-HTF track aims to strengthen the U.S. economy, improve worker performance and job satisfaction, and facilitate life-long learning. Some example projects for the FW-HTF track include efforts to match workers with jobs of the future and to develop living laboratories, such as in classrooms and manufacturing environments, where hypotheses about learning and productivity will be tested. The actual sub-tracks will be informed by analysis of emerging foundational advances in FW-HTF research and input from stakeholders. The FW-HTF track will align with, build upon, and help reshape directorates' foundational research investments. For more information on NSF C-Accel, please refer to the NSF C-Accel narrative in this chapter.

Foundational Activities

These activities comprise continued investments by participating directorates and offices in existing (ongoing) NSF programs that have laid the foundation for the FW-HTF Big Idea and FW-HTF Track in the C-Accel and will continue to be aligned with FW-HTF goals. These foundational programs are currently managed by NSF's directorates and offices and will remain within the directorates and offices with respect to their funding and management.

NAVIGATING THE NEW ARCTIC (NNA)

NNA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (GEO)	**-**	**-**	**$30.00**
Foundational Activities	**$23.67**	**-**	**$13.00**
BIO	1.50	-	1.50
EHR	-	-	1.25
ENG	2.84	-	2.00
GEO	0.50	-	1.75
SBE	0.38	-	0.50
OISE	1.00	-	1.00
OPP	17.45	-	5.00
Total	**$23.67**	**-**	**$43.00**

Overview

Arctic temperatures are warming faster than nearly everywhere else on Earth, with some models predicting that continued warming could produce an ice-free Arctic Ocean by mid-century. The rapid and wide-scale changes occurring in response to this warming portend new opportunities and unprecedented risks to natural systems; social and cultural systems; economic, political and legal systems; and built environments of the Arctic and across the globe. The lack of scientific observations and the prevalence of interdependent social, natural, and built systems in the Arctic make it challenging to predict the region's future. Understanding and adapting to a changing Arctic will require creative new directions for Arctic-specific research, education, workforce development, and leveraging of science, engineering, and technology advances from outside the Arctic.

NNA, one of NSF's 10 Big Ideas, embodies the Foundation's forward-looking response to these profound challenges. NNA seeks innovations in Arctic observational networks and fundamental convergence research across the social, natural, environmental, computing and information sciences and engineering that address the intersection of natural, social, and built systems. By drawing upon expertise from across the agency, NNA investments will accelerate research needed to inform decisions regarding the economy, security, and resilience of the U.S. as an Arctic Nation. On the observing front, NNA will advance and address key gaps in the existing array of observational networks, leveraging resources with the Mid-scale RI Big Idea as appropriate. NNA will also support knowledge co-production with indigenous and local people to enhance observations in key areas. Interagency, state government, and international partnerships will be further developed in order to achieve pan-Arctic and Arctic-global perspectives.

NNA will provide support for research activities that advance understanding of the social changes underway, including shifting demographics, changing ways of life, and traditional ecological and other knowledge in danger of being lost. Researchers will also examine economic, cultural, and social impacts on groups and communities living in regions impacted by Arctic changes in order to better understand how the social, economic, and governance systems interact with infrastructure such as the delivery of services and access to resources. Findings from this research can help to anticipate social changes that are likely to emerge from increased economic activity.

NNA-supported data efforts will enable major advances in modeling and prediction of Arctic systems and their global interactions. Strong coupling of observations, computation, and theory will be supported to ensure progress. NNA will leverage investments through the HDR Big Idea by federating data systems supported by NSF and interagency and international partners so that data can be readily discovered, accessed, and interoperated to facilitate more rapid theory and idea development and testing.

NNA will build on NSF's STEM investments and the NSF INCLUDES Big Idea to encourage innovative and appropriately evaluated education and public engagement efforts that leverage exciting NNA science and inspire diverse participation in STEM. NSF plans to invest in NNA through FY 2023.

Goals

1. Improved understanding of Arctic change and its local and global effects that capitalize on innovative and optimized observation infrastructure, advances in understanding of fundamental processes, and new approaches to modeling interactions among the natural environment, built environment, and social systems.
2. New enhanced research communities that are diverse, integrative, and well-positioned to carry out productive research at the intersections of Arctic natural and built environments and social systems.
3. Research outcomes that inform U.S. national security and economic development needs in the Arctic and enable resilient, sustainable Arctic communities.

In FY 2017, NSF issued a Dear Colleague Letter (DCL) on the GCR Big Idea (NSF17-065) to explore Convergence approaches within four of the research-focused NSF Big Ideas including NNA. This DCL requested proposals for Research Coordination Networks (RCNs), workshops, and activities to enhance Arctic observational systems. In FY 2018, NSF issued a DCL on Stimulating Research Related to NNA (NSF18-048), requesting proposals for workshops, RCNs, and proposals be submitted to the Arctic Sciences program in OPP. NSF awarded 25 new projects under these two DCLs and related opportunities. In FY 2019, NSF issued a solicitation for NNA (NSF19-511) and plans to make approximately 25 awards to support research grants, and planning grants that develop convergence research teams.

FY 2020 Investments

NSF's NNA activities in FY 2020 will focus on enabling advances in priority areas, which will be developed by building on outcomes from FY 2017 – FY 2019 activities. In 2019, NNA focused on advances in observing technologies and convergent social/built/natural environment systems science. FY 2020 support for this investment will continue, and NSF expects to issue another solicitation in FY 2020.

NSF will also continue coordination and leveraging of NNA-related activities with external stakeholders, including other federal agencies through the Interagency Arctic Research Policy Committee chaired by the NSF Director, local residents and indigenous peoples through state and local governance structures of Alaska, as well as with international partners through fora such as the biannual International Arctic Science Ministerial. All of the identified FY 2020 NNA activities will support goals 1, 2, and 3.

THE QUANTUM LEAP (QL)

QL Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (MPS)	**-**	**-**	**$30.00**
Foundational Activities	**$90.37**	**-**	**$36.00**
BIO	-	-	1.00
CISE	6.83	-	2.00
ENG	9.60	-	2.00
MPS	73.94	-	30.00
OISE	-	-	1.00
Total	**$90.37**	**-**	**$66.00**

Overview

The QL Big Idea will build upon and extend our existing knowledge of the quantum world to observe, manipulate, and control, from first principles, the behavior of particles at atomic and subatomic scales. It will enable discoveries in both naturally-occurring and engineered quantum systems and develop next-generation quantum technologies and devices for sensing, information processing, communications, and computing. These advances will unleash the potential of the Nation's quantum-based scientific enterprise to enhance the Nation's well-being, economy, and security.

NSF envisions a platform for the advancement of our fundamental understanding of how quantum phenomena at subatomic scale are manifested at the macroscopic scale. Discovery will lead to new methods of characterization and control, enhance predictive and modeling capabilities, and lead to new computing and networking paradigms. A cross-disciplinary approach combining expertise from multiple NSF scientific areas and a strong coupling of experimentation, computation, and theory will facilitate progress. Cross-disciplinary approaches will help identify the knowledge and skills necessary for the responsible conduct of quantum research to make fundamental advances in quantum science. Educational research on the learning and teaching of quantum concepts will contribute to the development of the future quantum workforce.

QL investments will empower U.S. scientists and engineers to advance quantum technologies and understanding, which will in turn lead to the discovery of novel materials, tools, devices, algorithms, simulations, systems, and programming paradigms, as well as new and creative application domains, along with a quantum-capable workforce. NSF's level of investment in QL is strongly aligned with Administration priorities on Quantum Information Science (QIS) and the National Quantum Initiative and will consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts. NSF will also broadly engage scientific, engineering, and educational communities, building a human capital foundation in pursuit of a better understanding of quantum phenomena.

Through a subcommittee of the National Science and Technology Council on QIS, NSF coordinates QL activities with other federal agencies and regularly holds meetings to assess and recommend government-wide strategies. Consistent with and crucial to its mission, NSF will seek to form partnerships with other federal agencies, industry, private foundations, national laboratories, and existing centers in order to leverage NSF investments in QL. NSF will seek to increase international cooperation with like-minded partners consistent with the Office of Science and Technology Policy National Strategic Overview for the closely connected area of QIS.

Goals

1. Understand fundamental limitations in time, distance, and scale for entanglement and coherence of quantum states.
2. Learn from quantum phenomena in naturally-occurring and engineered quantum systems, including emergent behavior, complexity, the quantum-classical boundary, and theoretical foundations.
3. Galvanize the science and engineering community to enable quantum discoveries, devices, systems, and technologies that surpass classical capabilities.

FY 2020 Investments

QL activities will focus on enabling advances in selected priority areas, sustaining the NSF QL community, building on outcomes from FY 2018 and FY 2019 activities, and adjusting emphases, as warranted. In FY 2020, a particular focus will be on team efforts to address important challenges in QIS, including but not limited to quantum computing and communications. Funding mechanisms will include targeted solicitations, Dear Colleague Letters, and other existing mechanisms such as Research Advanced by Interdisciplinary Science and Engineering, EAarly-concept Grants for Exploratory Research, Industry-University Cooperative Research Centers, and Ideas Labs. NSF also will continue coordination and leveraging of quantum-related activities with external stakeholders, including other federal agencies and the private sector.

A Quantum Idea Incubator, prototyped in FY 2018 through the RAISE funding mechanism, was established in FY 2019 through the solicitation "Enabling Quantum Leap: Quantum Idea Incubator for Transformational Advances in Quantum Systems (QII-TAQS)[1]". QII-TAQS established collaborations to develop functional demonstrations of quantum devices, systems, and/or applications, that will continue to receive funding in FY 2020. A Quantum Challenge Institutes solicitation, "Quantum Leap Challenge Institutes (QLCI)[2]", supporting center-scale quantum activities, was issued in February 2019 and will continue to expand in FY 2020. QLCI research will identify and address science and engineering challenges in addressing fundamental at-scale problems in quantum communication, quantum computing, quantum sensing, and quantum simulations. Other QL activities in FY 2020 include increasing support for accelerated quantum materials design, synthesis, characterization, and translation for quantum devices, systems, and networks as part of the FY 2019 solicitation, "Enabling Quantum Leap: Convergent Accelerated Discovery Foundries for Quantum Materials Science, Engineering, and Information (Q-AMASE-i)[3]."

[1] www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf19532
[2] www.nsf.gov/publications/pub_summ.jsp?org=NSF&ods_key=nsf19559
[3] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505504

UNDERSTANDING THE RULES OF LIFE: PREDICTING PHENOTYPE (URoL)

URoL Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (BIO)	**-**	**-**	**$30.00**
Foundational Activities	**$118.18**	**-**	**$85.00**
BIO	35.00	-	30.00
CISE	6.00	-	5.00
ENG	10.03	-	3.00
GEO	4.00	-	4.00
MPS	53.65	-	39.00
SBE	4.50	-	4.00
IA	5.00	-	-
Total	**$118.18**	**-**	**$115.00**

Overview

Imagine a world where we can forecast how life will respond to a changing planet and where we can prevent the emergence of infectious diseases and other dangerous species; a world where a bio-economy uses bioengineered organisms to ensure human and environmental well-being and provides a safe and stable food supply; and a world where genetic and neurodegenerative disease is a thing of the past. Recent advances in understanding and engineering organisms at the fundamental level of the genome place us on the cusp of turning this vision into reality, of re-engineering cells, organisms, and natural systems, and of creating innovative biochemicals and biomaterials that sustain a vibrant bio-economy and strengthen society. Understanding the rules that govern how key features of life, such as robustness, resilience, and adaptability, emerge from the interaction of genome, phenotype, and environment, through convergence approaches of all NSF science and engineering will provide a framework for the design of new biological systems from the molecular to ecosystem scale that will enhance human well-being.

The NSF Big Idea, URoL, aims to create a new paradigm at the convergence of science, engineering, and technology that will elucidate theoretical frameworks (rules) to enable prediction of the diversity of evolutionary solutions that biological systems use to support life processes seen across the planet. URoL also aims to train the next generation of researchers capable of using those rules/theories not only to predict the behavior of biological systems, but to design biological systems that benefit humankind.

NSF released a number of dear colleague letters (DCLs) to announce URoL opportunities for catalytic activities in FY 2018. Building on those catalytic activities, in FY 2019, NSF anticipates funding projects submitted in response to two Foundation-wide URoL solicitations: *Understanding the Rules of Life: Synthetic Cell: An Ideas Lab Activity*[1] and *Understanding the Rules of Life: Epigenetics*.[2] NSF anticipates URoL will run through FY 2023.

Goals

1. To support a convergence of science, engineering, and technology in discovery of rules governing the emergence of robust, resilient, and adaptable phenotypes at three levels of biological organization: (1)

[1] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505600
[2] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505582

cells and cell systems; (2) multi-cellular organisms and their co-dependent microbial associations; and (3) complex networks of organisms and species involving social, ecological, and population dynamics. These rule sets are referred to as, respectively, minimal rules, interaction rules, and complexity rules. Understanding the rules at these three different scales should enable the prediction of the behavior of biological systems and how those systems interact with, respond to, and modify the environment, and will facilitate the design of new biological systems at each scale that can serve humankind.

2. To support the discovery of scale invariant rules that govern biological systems. These theories should begin to explain the existence of a diversity of solutions that biology creates and uses to solve the essential problems of living systems at all scales: maintenance and transmission of information (genome), capture and conversion of raw materials to make the biochemicals and biomaterials that make up a living system, capture and conversion of energy to support all life processes, and reproduction to perpetuate the species. These universal, scale-invariant rules will serve to help improve human health and safety (e.g., agricultural adaptability, food safety, and environmental sustainability).
3. To support networks of researchers, technology developers, and educators engaged in URoL activities such that a robust community is developed, with an impact that is sustained beyond the five-year investment in the URoL Big Idea. The convergence nature of research addressing emergent properties of life stimulates technological innovation that feeds back to drive the science forward. This includes development of: new and improved techniques in molecular, genomic, and cellular examination and manipulation; improved technologies for the capture, analysis, and interpretation of biological, behavioral, and social phenotypic data in free-living organisms; new sensors and observing capabilities from nano- to macro-spatial and temporal scales; more capable cyberinfrastructure to support robust, data- and computational-enabled URoL discovery and sharing of research results; new approaches for data analysis, such as machine learning; advances in computation and complex modeling to support learning and simulation-driven URoL investigations; and advances in theory coming from all of these sciences and engineering. The predictive goals of URoL also guide investments in training and workforce development to produce scientists that have a firm grounding in the life sciences as well as the mathematical, physical, computational, behavioral and/or social sciences and engineering that enable them to work collaboratively across disciplinary boundaries. Finally, URoL provides a rich context in which to expand science literacy efforts, in both formal and informal learning environments, aimed at diverse communities across the nation. Research networks provide a mechanism for sustained support of distributed groups of investigators all working to achieve URoL goals.

FY 2020 Investments

FY 2020 activities will build upon the investments made in FY 2019. New solicitations will be released to support networks of researchers, technology developers and educators (Goal 3), as well as research to elucidate interaction rules (Goal 1). In addition, new catalytic activities, including workshops and exploratory grants, will be awarded in FY 2020 to seed investments in convergence approaches to the discovery of scale invariant rules that govern biological systems (Goal 2), which will be fully funded in future years.

WINDOWS ON THE UNIVERSE (WoU)

WoU Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (MPS)	**-**	**-**	**$30.00**
Foundational Activities	**$24.66**	**-**	**$24.50**
MPS	24.66	-	22.50
OPP	-	-	2.00
Total	**$24.66**	**-**	**$54.50**

Overview

For millennia, humankind has viewed the universe through the optical part of the electromagnetic spectrum to which human eyes are sensitive. Over the last half century, this range has been extended to observe electromagnetic radiation across the full spectrum from radio waves to X-rays and gamma rays. Observatories constructed and operated over the past two decades have extended this view to include high-energy particles such as neutrinos and cosmic rays. Most recently, with LIGO, NSF has established the ability to view the universe through gravitational waves. This ushers in the era of multi-messenger astrophysics. The three messengers—electromagnetic radiation, high-energy astrophysical particles, and gravitational waves—each provide unique information. Together, they provide a detailed picture of the Universe that allows scientists to study matter, energy, and the cosmos in fundamentally new ways—through several powerful and diverse "windows". WoU will build these capabilities and accelerate the synergy and interoperability of the three messengers to realize integrated, multi-messenger astrophysical explorations of the Universe.

Prior investments have led to important recent discoveries that demonstrate the power of WoU. The coincident detection of gravitational waves and electromagnetic radiation identified a merging binary neutron star system, confirmed Einstein's theory of General Relativity, and revealed critical information on the origin of heavy elements. Recent observations of high energy neutrino emission coincident with gamma-ray flares from the nucleus of an active galaxy have revealed for the first time an astrophysical source of high energy cosmic rays. These discoveries, along with others, have heralded the era of multi-messenger astrophysics.

WoU is anticipated to be a 10-year effort and builds upon decades of prior investments in individual and large-scale efforts. These include both presently operating observatories such as IceCube (for the detection of high-energy neutrinos) and LIGO (for the detection of gravitational waves) as well as development efforts for future experiments. In the FY 2019 Request, stewardship funding for WoU was first introduced and was complemented by the ongoing investments in foundational activities aimed at building capabilities for each of the three messengers. This funding strategy (stewardship funding supplemented with investments in foundational activities) will continue in FY 2020. These investments will also serve to grow the workforce not only for multi-messenger astrophysics but also for engineering, data science, and many other areas.

Goals

The overarching goal of WoU is to build the capabilities and accelerate the synergy and interoperability of the three messengers to realize integrated, multi-messenger astrophysical explorations of the Universe. There are three focus areas:

1. *Enhancing and accelerating the theoretical, computational, and observational activities within the scientific community*: Support efforts within the scientific community to build the observational and analysis capabilities in each of the three window areas, integrate the different research communities to develop full interoperability between the three windows, and develop a new workforce that is skilled in this new paradigm.
2. *Building dedicated mid-scale experiments and instrumentation*: Construct experiments and instrumentation in the mid-scale project range that will make critical contributions to the multi-messenger research infrastructure by enabling new capabilities in energy range or sky coverage, improved sensitivity, or new computational capabilities. The Big Idea: Mid-scale Research Infrastructure program, described elsewhere in this chapter, is an essential part of realizing this goal.
3. *Exploiting current facilities and developing the next generation of observatories*: Enhance infrastructure and provide modest upgrades to enable full utilization of the current generation of multi-messenger facilities, and support planning and development for the next generation of observatories to accelerate progress to realize significantly greater capabilities and extend the scientific reach.

FY 2020 Investments

WoU is implemented through a new and dedicated program, "Windows on the Universe: The Era of Multi-Messenger Astrophysics (WoU-MMA)."[1] The WoU-MMA program includes the Division of Astronomical Sciences and the Division of Physics within MPS, and OPP within GEO. The WoU-MMA program will address all of the WoU goals. Stewardship funding ($30.0 million) will reside in the MPS Office of Multidisciplinary Activities but will be allocated to awards from all participating divisions and directorates on the basis of merit and portfolio balance. Participating divisions and offices may elect to supplement this allocation through foundational activities in core research programs in order to advance particularly compelling scientific opportunities related to WoU. For MPS this is expected to be primarily in research grants in astronomy, particle astrophysics, and gravitational physics. OPP will supplement the WoU allocation with grants from the Antarctic Astrophysics and Geospace Sciences Program.

[1] PD 18-5115: www.nsf.gov/funding/pgm_summ.jsp?pims_id=505593

GROWING CONVERGENCE RESEARCH (GCR)

GCR Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
IA	$5.00	-	$16.00

Overview

GCR empowers the U.S. research community to leverage multiple scientific and engineering (S&E) disciplines and develop novel research strategies to address extremely challenging and complex problems. GCR research challenges are inspired by deep scientific questions or pressing societal needs and require the integration of multi-disciplinary perspectives. GCR is an "enabling" Idea within NSF's 10 Big Ideas.

The grand challenges of today—such as exploring the universe at all scales; developing infrastructure resilient to extreme events and geo-hazards; combining biology, chemistry, engineering, and computer science to produce the machines and materials of the future; and creating the breakthroughs that will enable the industries of the future—will not be solved by one discipline alone. They require convergence: the merging of ideas, approaches, tools, and technologies from widely diverse fields of knowledge to stimulate innovation and discovery. Key reports describing the importance of convergence for the research ecosystem include Massachusetts Institute of Technology (MIT) reports from 2011[1] and 2016,[2] National Academies of Science, Engineering, and Medicine reports from 2014[3] and 2017,[4] and a 2013 report published by Springer.[5] These reports emphasized the importance of convergence approaches to S&E research to address grand challenges and underlined the importance of team science to such efforts. These reports also emphasized the role of federal funding agencies in realizing the benefits of convergence, namely, that federal agencies should expand mechanisms for funding convergence research.

Convergence research is a means of solving vexing research problems. The unifying characteristics of these problems are that: (a) if successfully answered, they are likely to have a large impact, either on fundamental understanding in S&E or on the Nation's ability to meet pressing societal challenges, or both; and (b) they require the integration of knowledge, tools, and ways of thinking from multiple disciplines.

Goals

The goals of the GCR Big Idea are:
1. Catalyze convergence approaches to compelling scientific and engineering research problems at the intersection of existing disciplines; and
2. Enhance NSF's review process to more effectively assess the merit of convergence research proposals.

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[1] The Third Revolution: The Convergence of the Life Sciences Physical Sciences, and Engineering. Cambridge, MA: Massachusetts Institute of Technology. www.aplu.org/projects-and-initiatives/research-science-and-technology/hibar/resources/MITwhitepaper.pdf
[2] Convergence: The Future of Health. Cambridge, MA: Massachusetts Institute of Technology. www.convergencerevolution.net/s/Convergence-The-Future-of-Health-2016-Report-55pf.pdf
[3] Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. Washington, D.C.: The National Academies Press. www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering
[4] *A New Vision for Center-Based Engineering Research*. Washington, DC: The National Academies Press. www.nap.edu/catalog/24767/a-new-vision-for-center-based-engineering-research
[5] Convergence of Knowledge, Technology, and Society. www.springer.com/us/book/9783319022031

Approach

GCR will strengthen the global competitiveness of the U.S. S&E enterprise by growing a new generation of convergence researchers skilled at working in teams and able to respond rapidly to new research challenges. To support convergence research, NSF will enhance its review processes by addressing the key technical, organizational, and logistical challenges that hinder the evaluation of truly integrative research. GCR's strategic investments in emerging convergence research themes will support the development of new fields of inquiry, discovery of the knowledge necessary for society to develop solutions or technologies to address important societal challenges, and the training of a new generation of convergence researchers.

GCR will use several mechanisms to accomplish programmatic goals, including:

- Capacity-Building Activities: GCR will seek to broaden the range of those engaged in convergence efforts. A portion of the GCR funds will be invested in capacity-building activities, such as workshops, Ideas Labs, and Research Coordination Networks (RCNs). NSF remains open to novel approaches to capacity-building that may be suggested by researchers and other stakeholders. One goal of capacity-building will be to foster new partnerships between U.S. academic researchers and other sectors such as industry, federal laboratories, non-profit research organizations, and the international research community. Another emphasis will be to broaden the demographic diversity of teams participating in convergence research. GCR began in FY 2017 by funding capacity-building activities aimed at addressing grand challenges within NSF's 10 Big Ideas.[6]
- Exploration Grants: NSF will fund exploratory grants to enable research teams to demonstrate their ability to collaborate effectively; resolve epistemological and ontological differences between disciplines; begin the process of integrating conceptual models, tools, methodologies, and infrastructure; and show progress on their convergence research projects. Exploratory grants are expected to have budgets of up to $3.60 million and durations of up to five years. Exploratory grants will prepare research teams for larger scale convergence research awards through programs such as Science and Technology Centers, Engineering Research Centers, and NSF Research Traineeships. NSF announced the first exploratory grant opportunity in FY 2018[7] for awards in FY 2018 and FY 2019. In February 2019, GCR released a new solicitation, NSF 19-551, announcing opportunities for funding in FY 2019 and FY 2020. [8]
- Enhanced Merit Review Process: An enhanced merit review process will be employed for convergence research projects. NSF will identify a cadre of experienced convergence researchers using data-mining tools, the knowledge of program staff, and suggestions from learned societies. Within this group, NSF will ask a diverse pool of researchers to participate in a College of Reviewers (CoR). The CoR will be a resource that will enable NSF staff to recruit appropriate reviewers for convergence research.

FY 2020 Investments

GCR funded activities in FY 2020 include:

- Targeted, capacity-building activities in emerging convergence research themes will emphasize activities that strengthen links between researchers and other stakeholders (up to $1.60 million). Up to four such activities are anticipated.
- Exploration grant support will continue into FY 2020, giving teams opportunities to explore emerging convergence research challenges and begin integration of tools, techniques, data archives, and knowledge. About 10 to 12 awards are anticipated. Initial funding for these awards is expected to total

[6] GCR funded 23 new activities including: a Quantum Science Summer School; a RCN that brings together natural, physical, social, and information scientists, and indigenous scholars to advance the understanding of rapid changes in the Arctic; and a RCN in which early- and mid-career scientists explore one of the most profound and persistent topics in biology, the origins of life.
[7] "Dear Colleague Letter: Growing Convergence Research," (NSF 18-058) www.nsf.gov/pubs/2018/nsf18058/nsf18058.jsp. This resulted in seven awards in FY 2018. Five to six additional awards are anticipated in FY 2019.
[8] www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=505637&ods_key=nsf19551

approximately $14 million.

- Additional experts will be recruited to expand the Convergence CoR.

INCLUSION ACROSS THE NATION OF COMMUNITIES OF LEARNERS OF UNDERREPRESENTED DISCOVERERS IN ENGINEERING AND SCIENCE (NSF INCLUDES)

NSF INCLUDES Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Stewardship Activities (EHR)	**-**	**-**	**$20.00**
Foundational Activities	**$17.95**	**-**	**-**
BIO	1.40	-	-
CISE	1.93	-	-
EHR	5.47	-	-
ENG	1.41	-	-
GEO	2.44	-	-
MPS	2.83	-	-
SBE	0.58	-	-
IA	1.90	-	-
Total	**$17.95**	**-**	**$20.00**

Overview

The NSF INCLUDES Big Idea aims to develop a talented, innovative, and capable STEM workforce that reflects the diversity of the Nation. For the United States to remain the world leader in STEM innovation and discovery, it must identify and develop talent from all sectors 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 NSF's commitment to broadening participation.

NSF INCLUDES is NSF's response to the Committee on Equal Opportunities in Science and Engineering's (CEOSE) 2011-2012 Biennial Report to Congress[1] recommending:

> "NSF implement a bold new initiative focused on broadening participation of underrepresented groups in STEM, similar in concept and scale to NSF's centers, that emphasizes institutional transformation and system change; collects and makes accessible longitudinal data; defines clear benchmarks for success; supports the translation, replication, and expansion of successful broadening participation efforts; and provides significant financial support to individuals who represent the very broadening participation that we seek" (p. v).

As part of NSF's continuing response to CEOSE's recommendation, NSF has committed to a plan spanning ten-years, FY 2016 – FY 2025. Specifically, NSF is investing in developing and sustaining the NSF INCLUDES National Network. The overarching goal for NSF INCLUDES is to achieve significant impact at scale in transforming STEM education and workforce development. To achieve this vision, NSF is funding a suite of projects, including NSF INCLUDES Design and Development Launch Pilots (funded in FY 2016 and FY 2017), NSF INCLUDES Alliances (funded in FY 2018 and FY 2019), and an NSF INCLUDES Coordination Hub (funding commenced in FY 2018). These activities form the foundation for the NSF INCLUDES National Network. Opportunities to join the NSF INCLUDES National Network have been extended to other NSF-funded projects through on-ramps and language in more than 10 EHR and

[1] www.nsf.gov/od/oia/activities/ceose/reports/Full_2011-2012_CEOSE_Report_to_Congress_Final_03-04-2014.pdf)

R&RA program solicitations inviting projects that align with the principles of NSF INCLUDES. Other organizations (e.g., K-12 school districts, colleges and universities, professional organizations, government agencies, foundations, businesses and industries) will also be able to join the NSF INCLUDES National Network and support its goals. NSF INCLUDES Alliances will serve as test beds for designing, implementing, studying, and refining change models that are based on collective impact-style approaches.[2] Thus, the NSF INCLUDES investment will provide valuable evaluation knowledge that will strengthen this initiative and contribute to NSF's understanding of strategies for addressing the Nation's most challenging diversity and inclusion issues.

Goals

NSF INCLUDES investments target the following three strategies:
1. Broadening Participation (BP) in STEM Research: Synthesize and build the research base for broadening participation in STEM and foster the spread and adaptation of proven effective practices.
2. Shared Goals and Objectives: Support stakeholders as they identify shared goals and objectives, including those from specific STEM disciplines. The attainment of shared goals and objectives will be essential for success in achieving inclusion in high-quality, STEM learning opportunities, and in the Nation's scientific workforce.
3. NSF INCLUDES National Network: Support local and regional, discipline-specific, and crosscutting, multi-stakeholder partnerships and networks as part of the NSF INCLUDES National Network.

The NSF INCLUDES Big Idea rests on principles of collaborative change 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 and similar models for scaling and growth.[3] Since the program was launched in FY 2016, NSF has funded 70 Design and Development Launch Pilots. In total, the NSF INCLUDES Launch Pilots are engaging 758 partnering organizations in the important work of BP in STEM using innovative collaborative change approaches. BP challenges addressed in the projects include, but are not limited to, providing STEM engagement for students and communities to promote interest in future careers in STEM, enhancing support systems for undergraduate and graduate students, and expanding access to quality STEM education. Leadership, data collection, expansion, and sustainability are also emphasized. Elements of ten Design and Development Launch Pilots have been incorporated into Alliances that were funded in FY 2018. The progress for the first two years of the program is summarized in the NSF INCLUDES Report to the Nation released in January 2018.[4] A second report on the progress of the program will be published in December 2019.

NSF INCLUDES is guided by a detailed theory of change and includes principal investigator interviews and focus groups, NSF stakeholder interviews, technical assistance evaluation, and ongoing portfolio analysis. The first internal Annual Evaluation Report, released in 2018, featured efforts to build and measure collaborative infrastructure via a shared vision, partnerships and networks, common metrics, and communication needed to produce collaborative change. A Dear Colleague Letter, NSF 17-111, resulted in 14 EArly-concept Grants for Exploratory Research (EAGERs), conferences, and supplement awards in existing BP programs, thus providing on-ramps to the NSF INCLUDES portfolio. The NSF INCLUDES National Network added five NSF INCLUDES Alliances and one Coordination Hub in FY 2018. The Alliances focus on diversifying graduate education programs and STEM faculty, providing research experiences for rural first-generation college students, preparing community college students for advanced

[2] Kania, J., & Kramer, M. (Winter 2011). Collective impact. Stanford Social Innovation Review. Retrieved from: http://ssir.org/articles/entry/collective_impact). Kania and Kramer note that collective impact "requires a systematic approach to social impact that focuses on relationships between organizations and the progress toward shared objectives," p. 5.
[3] Kania, J., & Kramer, M. (Winter 2011). Collective impact. Stanford Social Innovation Review. Retrieved from: http://ssir.org/articles/entry/collective_impact)
[4] www.nsf.gov/news/special_reports/nsfincludes/pdfs/INCLUDES_report_to_the_Nation.pdf

mathematics, and expanding the participation of underrepresented groups in computing fields. Additional NSF INCLUDES Alliances will be funded in both FY 2019 and FY 2020, and other funding mechanisms (e.g. supplements, pilot projects, planning grants, and starter networks) will funded, serving as on-ramps to the NSF INCLUDES Alliances and National Network.

FY 2020 Investments

In FY 2020, NSF plans to invest $20.0 million in NSF INCLUDES.

Goal 1: Broadening Participation in STEM Research

- NSF INCLUDES will continue to fund BP projects and related research through NSF INCLUDES Alliances and the existing NSF BP portfolio such as pilot projects, planning grants, and starter networks (e.g., research coordination networks) that serve as on-ramps to the NSF INCLUDES Alliances and the NSF INCLUDES National Network.
- NSF INCLUDES will support the dissemination and adaptation of proven strategies for expanding the use of innovative and collaborative BP practices in the NSF INCLUDES National Network and NSF's existing BP portfolio.

Goal 2: Shared Goals and Objectives

- NSF will provide ongoing funding to the NSF INCLUDES Coordination Hub, which was first funded in FY 2018, to oversee the implementation of a system of measurement, communication, and mutually reinforcing activities across the NSF INCLUDES National Network.
- NSF will support connections of existing NSF BP programs and other NSF-funded projects that support the NSF INCLUDES vision to the NSF INCLUDES National Network using existing funding mechanisms (e.g., supplements) or other innovative approaches to engage all NSF directorates and offices.
- NSF will develop a comprehensive evaluation, monitoring, and feedback framework for the NSF INCLUDES National Network, implemented in conjunction with the NSF INCLUDES Coordination Hub, which will include indicators and measures for tracking progress towards the achievement of the project goals of the NSF INCLUDES National Network.

Goal 3: NSF INCLUDES National Network

- NSF will fund NSF INCLUDES Alliances, which are five-year, center-scale projects committed to solving a specific set of objectives. NSF INCLUDES Alliances will leverage existing Design and Development Launch Pilots, programs, people, organizations, technologies and institutions to catalyze NSF's BP investments. FY 2020 funding will provide ongoing support to NSF INCLUDES Alliances funded in FY 2018 and FY 2019.
- NSF will regularly convene principal investigators of NSF INCLUDES Launch Pilots, Alliances, and the Coordination Hub to discuss BP challenges, proposed strategies, scaling mechanisms, and the feasibility of sustaining projects.

MID-SCALE RESEARCH INFRASTRUCTURE (MID-SCALE RI)

Mid-scale RI Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
MREFC	-	-	$45.00
R&RA (IA)	-	-	30.00
Total	**-**	**-**	**$75.00**

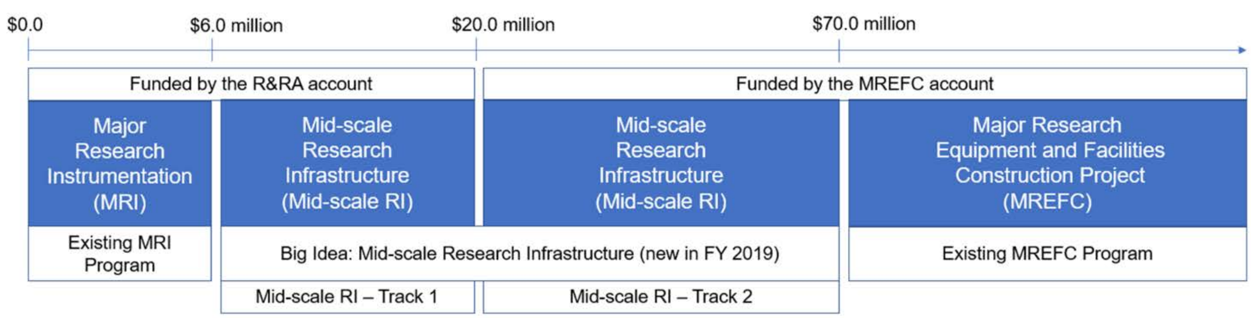
Overview

Mid-scale Research Infrastructure (Mid-scale RI) is an NSF-wide effort to meet the research community's needs for modern research infrastructure to support exciting science and engineering research. Mid-scale RI is an "enabling" Big Idea to implement agile mechanisms for funding experimental research capabilities costing between $6.0 million and $70.0 million. The objective is to transform individual scientific and engineering research fields with new infrastructure, while simultaneously training early-career researchers in the development, design, construction, and use of cutting-edge infrastructure.

The scientific importance of mid-scale research infrastructure is reflected in the 2017 American Innovation and Competitiveness Act (AICA), which directed NSF to "evaluate the existing and future needs, across all disciplines supported by the Foundation, for mid-scale projects." Responding to Congress, the National Science Board report, "Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure and Cyberinfrastructure at NSF",[1] highlights that:

> "The research community has identified mid-scale research infrastructure as a key enabler of scientific advances on shorter timescales than required for the larger projects funded within the MREFC account. ... Infrastructure investments at the required mid-level can also help maintain the United States' standing among global partners and competitors."

NSF Portfolio of Central Instrumentation and Infrastructure Implementation Programs



This graphic shows NSF-wide instrumentation and infrastructure programs. Information presented here focuses on the programs, Mid-scale RI - Track 1 (Mid-scale RI-1) and Mid-scale RI - Track 2 (Mid-scale RI-2) that constitute the Mid-scale RI Big Idea. Information on the complementary Major Research Instrumentation (MRI) program may be found in the Integrative Activities (IA) narrative, while information on the MREFC program may be found in the MREFC chapter. Combined, Mid-scale RI-1 and Mid-scale RI-2 support the implementation of research infrastructure at scales that are above what is possible through the MRI program and below what has been funded through the MREFC account. Mid-scale RI-2 awards

[1] www.nsf.gov/nsb/publications/2018/NSB-2018-40-Midscale-Research-Infrastructure-Report-to-Congress-Oct2018.pdf

are distinguished from Mid-scale RI-1 awards by the scale, risks and consequent oversight mechanisms associated with the projects.

These two tracks are programs that have a strong scientific heritage within NSF and the community. The Mid-scale RI-1 program builds on the knowledge gained through NSF's stewardship of the MRI program. The new Mid-scale RI-2 program, funded through MREFC, builds on NSF's expertise in working with the research community to develop and implement large-scale, complex research infrastructure projects. Both programs will use lessons learned from past and existing infrastructure programs in individual directorates such as Next Generation Networks for Neuroscience in BIO, the Mid-Scale Innovations Program in MPS' Division of Astronomical Sciences, and Materials Innovation Platforms in MPS' Division of Materials Research.

Goals

1. Provide access to cutting-edge mid-scale research infrastructure, including instrumentation.
2. Enable agile development and implementation of frontier scientific and engineering research infrastructure with a high potential to significantly advance the Nation's research capabilities.
3. Train early-career scientists and engineers in the development and use of advanced research infrastructure that will enable them to make substantive scientific contributions and to envision and realize the larger-scale infrastructure that will transform entire disciplines.

FY 2020 Investments

The FY 2020 Request for Mid-scale RI is $75.0 million, which is to be split between two separate programs, Mid-scale RI-1 ($30.0 million) and Mid-scale RI-2 ($45.0 million). Mid-scale RI-1 will be funded through the R&RA account, and Mid-scale RI-2 will be funded through the MREFC account. Both programs address all three goals listed above.

In fall 2018, NSF issued two Mid-scale RI funding opportunities. One solicitation (Mid-scale RI-1, NSF-19-537)[2] includes an opportunity to propose Mid-scale RI projects with a total NSF project cost between $6.0 million and $20.0 million, while a second (Mid-scale RI-2, NSF-19-542)[3] includes an opportunity to propose projects with a total NSF cost between $20.0 million and $70.0 million. The resulting awards will be made in FY 2019 and FY 2020. Over the course of the two years, the anticipated number of awards is three to ten for Mid-scale RI-1 and four to six for Mid-scale RI-2.

[2] www.nsf.gov/pubs/2019/nsf19537/nsf19537.htm
[3] www.nsf.gov/pubs/2019/nsf19542/nsf19542.htm

NSF 2026

NSF 2026 Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
IA	-	-	$6.50

Overview

NSF 2026 is dedicated to growing and supporting new activities that set the stage for foundational, breakthrough discoveries and innovations in STEM and STEM education in anticipation of the Nation's 250th anniversary in 2026.

The overall objective of NSF 2026 is to provide a mechanism for identifying long-term (10 years or more), forward-looking agency initiatives in a systematic fashion and then funding their exploration. It will engage a variety of STEM research and education stakeholders and the general public in thoughtfully designed exercises to identify challenges requiring long-term support. It intends to reach beyond single disciplines, directorates, or priority areas and allow for a strategic, agency-level view of science and engineering horizons.

NSF 2026 aims to improve NSF's current process for identifying research areas for long-term investment. While program development occurs throughout NSF, it usually happens at the directorate or division level. Moreover, cross-cutting programs are typically developed on yearly budget cycles, which may limit vision and scope. NSF 2026, one of NSF's 10 Big Ideas, intends to transcend established scientific structures and go beyond standard operating procedures to ensure continuous exploration at the frontiers of discovery and innovation.

NSF 2026 began in FY 2018 with the launch of the first NSF 2026 Idea Machine,[1] which continues into FY 2019. An Idea Machine is a prize competition that invites a broad swath of stakeholders in the science, engineering, and STEM education research enterprise to identify some of the grand challenges for future, long-term investment by NSF, (e.g., to identify the next set of Big Ideas, themes for existing center-scale programs, or other new initiatives). Specifically, NSF is calling on science, engineering, and STEM education researchers from academia, industry, and non-profit organizations, teachers (who are encouraged to enter on behalf of their high school classes), and the public, more broadly, to enter the contest. The most promising entries (narratives and videos) will be posted for public comment and judged by panels of STEM experts from multiple stakeholder groups. The winning ideas will: (1) have the potential for significant scientific and societal impact; (2) can generate a great deal of excitement among judges and the public; and (3) be ambitious, original, timely, and beyond the scope of current and planned NSF activities. The winning entries will be awarded cash prizes and public recognition when the competition ends in fall 2019.

The name "NSF 2026" recognizes and celebrates the Nation's 250th anniversary; however, NSF anticipates that the procedures and policies resulting from this effort will contribute to the development of NSF's long-term investment strategies well beyond 2026. If successful, NSF 2026 will identify STEM research and education initiatives necessary to address the novel scientific and engineering challenges the Nation will face in 2026 and beyond. In addition, the activity will surface the best ways of eliciting the most forward-looking ideas and of supporting discoveries and discoverers over the next decade to sustain America's leadership in the science and engineering enterprise.

[1] www.nsf.gov/news/special_reports/nsf2026ideamachine/index.jsp

Goals

Overarching Goal: By enabling a broad consensus with respect to major initiatives that require and deserve long-term support, NSF 2026 will effectively bolster NSF's global leadership in fundamental science and engineering research and education, enabling discovery and innovation of unprecedented scale and impact.

The goals of the NSF 2026 Big Idea are:

1. Continue to evolve the Foundation's portfolio of major, long-term investment areas by exploring the winning ideas identified by the NSF 2026 Idea Machine.
2. Refine NSF's procedures for identifying future (FY 2021 through FY 2030) investments, including using novel and existing mechanisms to engage the broader community, such as the Idea Machine, Ideas Labs, and other forms of prize challenges and crowd sourcing. The frequency of these activities going forward will be informed by the outcome of the pilot run of the Idea Machine in FY 2018 and FY 2019.

FY 2020 Investments

Specific Investment 1: Preparing the research community to explore the NSF 2026 Idea Machine winning ideas.

In FY 2020, an investment of $5.50 million will support workshops, Research Coordination Networks (RCNs), and EArly-concept Grants for Exploratory Research (EAGERs), topically focused on the winning ideas identified by the 2018-2019 Idea Machine competition. These catalytic activities will support Goal 1, enabling NSF to refine the winning ideas identified by the Idea Machine. Subsequently, NSF will shape these winning ideas into actionable research themes that can be inserted into existing programs (e.g., Science and Technology Centers and NSF Research Traineeships) and/or into new, long-term NSF 2026 programs that will launch in FY 2021 and beyond. These activities will bring together researchers from multiple STEM disciplines to form collaborative teams, readying them to respond to the new NSF 2026 funding opportunities and tackle the grand challenges identified therein.

Specific Investment 2: Analysis, evaluation, and implementation.

An investment of $1.0 million will support the assessment of NSF's long-term research portfolio, the evaluation of the NSF 2026 Idea Machine and other processes that NSF uses to plan and develop its future long-term initiatives, and the incorporation of lessons learned into the design of the NSF 2026 activity. The assessment continues the work of tracking the evolving NSF portfolio and identifying gaps and opportunities, a critical exercise that will inform future long-term investment strategies at an agency-wide level. The evaluation will assess the success of the first Idea Machine, inform improvements to its design and execution, and support implementation of additional procedures to identify future investment priorities. Taken together, these activities will advance the Foundation's efforts to craft a flexible, sustainable, idea-generating process that can be tailored to meet particular needs and repeated as needed to ensure that NSF stays at the forefront of discovery and innovation. These activities support Goals 1 and 2.

INNOVATIONS AT THE NEXUS OF FOOD, ENERGY AND WATER SYSTEMS (INFEWS) **$15,000,000**
- $18,540,000 / -55.3%

INFEWS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
EHR	$11.40	-	-
ENG	6.73	-	5.00
GEO	7.00	-	8.00
MPS	0.01	-	-
SBE	2.50	-	2.00
OISE	0.90	-	-
IA	5.00	-	-
Total	**$33.54**	**-**	**$15.00**

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 FEW resources. 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. The INFEWS investment area enables interagency cooperation on pressing sustainability issues facing the Nation—understanding interactions across the FEW nexus, how it is likely to affect our water resources, and how we can proactively plan for its consequences.

Understanding the food, energy, and water nexus—its complex, coupled processes and systems function—is a grand research challenge. There is also a critical need for research to enable new technologies that will enhance the productivity of the system and subsystems, minimize 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 would not emerge from research on food or energy or water systems alone; research into 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. 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.

NSF has invested in discovery research at a disciplinary level, as well as cross-cutting research through programs such as Water, Sustainability and Climate; Dynamics of Coupled Natural and Human Systems; Sustainable Chemistry, Engineering and Materials; Cyber Innovation for Sustainability Science and Engineering; Interdisciplinary Research in Hazards and Disasters; and Basic Research to Enable Agricultural Development.

Building on prior investments, NSF launched INFEWS in FY 2016 to support fundamental scientific and engineering research for new technologies, design concepts, and development of solutions that address the complexity of the food, energy, and water nexus and its subsystems. The desired endpoint is to improve understanding of the interdependencies of the FEW systems, within a disciplinary and transdisciplinary context.

Under INFEWS, NSF partners with the United States Department of Agriculture National Institute of Food and Agriculture (USDA/NIFA) to combine resources to identify and fund high-impact projects that support their respective missions and foster collaboration between agencies and the investigators they support. In addition, NSF and USDA/NIFA promote international cooperation that links scientists and engineers from a range of disciplines and organizations to solve the significant global challenges at the nexus of FEW systems.

NSF plans to end formal investment in INFEWS at the end of FY 2020, and thus will undertake planning and strategizing exercises internally and in consultation with other federal agencies to determine which aspects of INFEWS should be supported through core programs and which aspects may become part of a different investment area or scientific thrust for the Foundation beyond FY 2020.

Goals

1. Significantly advance our understanding of the food-energy-water system through quantitative and computational modeling, including support for advanced relevant cyberinfrastructure;
2. Develop real-time, cyber-enabled interfaces that improve understanding of the behavior of FEW systems and increase decision support capability;
3. Enable research that will lead to innovative solutions to critical FEW system problems; and
4. Grow the scientific workforce capable of studying and managing the FEW system, through education and other professional development.

In FY 2016-2018, NSF issued solicitations to support research to advance all four goals of INFEWS. Two examples of funded research are: one research project examines approaches to managing food, energy, and water systems under stress in California; another project is conducting an analysis of interventions and the impacts of conservation on reducing household food, energy and water consumption.

In FY 2016-2017, NSF issued Dear Colleague Letters (DCLs) to support research activities in nitrogen, phosphorus, and water in the context of INFEWS. Research supported by these DCLs is advancing knowledge of the nitrogen and phosphorus cycles; the production and use of fertilizers for food production; and the detection, separation, and reclamation/recycling of nitrogen- and phosphorus-containing species in and from complex aqueous environments. One research project team is developing receptors to detect and measure nitrogen/phosphorous to improve accuracy and to inform decisions on fertilizer use and wastewater treatment. This project also provides undergraduate and graduate training and internship opportunities within the agricultural industry. Another project is providing information critical to restoring floodplain ecosystems in ways that maximize water quality improvements for nitrogen and phosphorous.

In FY 2019, NSF is in the process of reviewing and awarding grants from the FY 2018 solicitation as well as providing continuing support for ongoing projects. Also, in FY 2019, the INFEWS working group continues to coordinate with intra-agency, inter-agency, and international partners to identify and promote additional opportunities to support FEW- related research.

FY 2020 Investments

In FY 2020, NSF will continue to support ongoing awards made under the final INFEWS solicitation issued in March 2018. This funding will further INFEWS and NSF Strategic Plan objectives by continuing to build interdisciplinary and convergent research and innovation capabilities. Other activities contributing to INFEWS in FY 2020 will include ENG support for research related to the soil microbiome.

NSF INNOVATION CORPS (I-CORPS™) $33,000,000 +$180,000 / 0.5%

I-Corps™ Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$0.98	-	$1.00
CISE	11.64	-	13.80
EHR	0.20	-	-
ENG	17.20	-	15.40
GEO	0.60	-	0.60
MPS	1.70	-	1.70
SBE	0.50	-	0.50
Total	**$32.82**	**-**	**$33.00**

Overview

The NSF 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) that works cooperatively to build, utilize, and sustain the national innovation ecosystem. NIN supports innovation research and education and enhances the development of technologies, products, and processes that benefit society. NIN components are diverse in research areas, resources, tools, programs, capabilities, and geographic locations, while the network has the flexibility to grow or reconfigure as needs evolve. These components contribute to enhancing and enlarging the NIN's community of mentors, researchers, entrepreneurs, and investors.

The I-Corps™ program supports NSF's strategic vision of "A Nation that is the global leader in research and innovation." Specifically, I-Corps™ contributes directly to strategic objectives in NSF's 2018-2022 Strategic Plan including: objective 1.1, to "advance knowledge through investments in ideas, people, and infrastructure;" objective 2.1, to "support research and promote partnerships to accelerate innovation and to provide new capabilities to meet pressing societal needs;" and objective 2.2, to "foster the growth of a more capable and diverse research workforce and advance the scientific and innovation skills of the Nation."

I-Corps™ stimulates the translation of the results of basic research to societal impact and prepares the future workforce to contribute to both use-inspired research and the commercialization of ideas enabled by fundamental research. Additionally, Section 601 of the American Innovation and Competitiveness Act (AICA), signed into law in January 2017, stipulates that NSF shall carry out, further develop, and expand the I-Corps™ program and other training programs that focus on education in entrepreneurship and commercialization.

Goals

The specific goals of the I-Corps™ program are to:

1. Capitalize on NSF's investment in fundamental research;

2. Offer academic researchers an opportunity to learn firsthand about technology-based innovation and entrepreneurship, and thereby fulfill the promise of their discoveries;
3. Foster national collaborations of academic researchers with peers conducting research and commercialization, industrial mentors, startup investors, and entrepreneurial education; and
4. 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 2020 Investments

The I-Corps™ program currently has three components:

- I-Corps™ Teams are funded at $50,000 per Team with a duration of one year. NSF currently funds approximately 240 teams per year. NSF will grow the number of Teams trained through partnerships with other federal agencies and programs, states, and regional organizations, and will continue to identify and fund the best Teams emanating from fundamental, applied, and translational research funded across the Foundation.
- I-Corps™ Sites are funded at up to $100,000 per year for two to five years. NSF currently supports 100 active Sites.
- New I-Corps™ Nodes are supported for up to five years; funded at up to $1.20 million in year one, declining to $300,000 in year five. Renewing Nodes are funded at up to $900,000 in year one declining to $300,000 in year five. NSF currently supports nine Nodes.

To build on the I-Corps™ program's success and fully realize its potential to help expand the Nation's innovation ecosystem, NSF will scale up the I-Corps™ program. This scale-up calls for a strategy to provide I-Corps™ curriculum and experience to a much larger community of technology innovators and entrepreneurs who do not have prior connections with NSF and may otherwise not have access to the I-Corps™ curriculum. The expanded target community will include local and regional entrepreneurs, university spinoffs, and awardees of other federal agencies, state governments, and non-profit organizations. By leveraging existing entrepreneurial and innovation capacities in universities and tapping into federal, state, and regional resources, the I-Corps™ NIN, currently comprising Nodes and Sites, holds significant potential to reach out to a larger number of budding and existing innovators and entrepreneurs.

In FY 2018, NSF began planning for and experimenting with scaling up the I-Corps™ program nationwide by growing the network, including increasing the numbers of I-Corps™ Sites and Nodes. To further increase the pace of scale-up, NSF is developing a new NIN model, in which responsibilities for some I-Corps™ activities are redistributed. The network is expected to continue to be diverse, inclusive, and flexible. NSF anticipates rolling out this model in FY 2019 and FY 2020, while continuing to support new Teams and existing Nodes and Sites.

NSF will also continue to build NIN partnerships with stakeholders who have access to innovators and entrepreneurs, including federal agencies, state governments, universities, and non-profit organizations.

SECURE AND TRUSTWORTHY CYBERSPACE (SaTC) $128,340,000

-$5,990,000 / -4.5%

SaTC Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
CISE	$70.50	-	$65.00
EHR	55.09	-	55.09
ENG	3.25	-	3.25
MPS	1.49	-	1.00
SBE	4.00	-	4.00
Total	**$134.33**	**-**	**$128.34**

Overview

In today's increasingly networked, distributed, and asynchronous world, cybersecurity involves hardware, software, networks, data, people, and integration with the physical world. Seemingly overnight, society has become deeply reliant on the smooth functioning of its digital infrastructure. Unfortunately, attacks on corporations, agencies, national infrastructure, and individuals have exposed the fragility and vulnerability of this complex cyberspace. 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 is the most promising approach to develop better ways to design, build, and operate cyber systems; to protect existing and future infrastructure; and to motivate and educate individuals about cybersecurity. Achieving these goals not only requires expertise in computer science, engineering, statistics, mathematics, social, behavioral, and economic sciences, and education research, but also the translation of new concepts and technologies into practice.

SaTC is a multi-year investment area that began in FY 2012 and must evolve continuously to address new threats. Outcomes from SaTC include an organized scientific body of knowledge that informs the theory and practice of cybersecurity and privacy, and an improved understanding of the causes of and mitigations for current threats. SaTC contributes to the development of foundational countermeasure techniques leveraging sound mathematical and scientific foundations, principled design methodologies, and socio-technical approaches that consider human, social, organizational, economic, and technical factors, as well as design metrics for evaluating success or failure of these approaches. In the space of training and education, SaTC makes recommendations for new instructional materials, degree programs, and educational pathways. Foundational research in SaTC leads to a research community pursuing a broad and deep multidisciplinary research portfolio spanning cybersecurity and privacy, whose results underlie methods for securing critical infrastructure. Ultimately, through SaTC, NSF expects to produce an innovation ecosystem that ensures (a) new and existing technologies are secure from attacks and (b) users' information is protected from violations of privacy despite new attack surfaces that these technologies may present. Similarly, the creation of an American workforce and citizenry with an understanding of cybersecurity and privacy issues is one of the benefits of NSF's support for activities related to the education and training of cybersecurity researchers and professionals. As the goals of SaTC contribute to national security, NSF plans to continue investments in this area for the forseeable future.

Goals

1. Foundational Research: Develop the scientific theory, methodologies, and tools necessary for the development of trustworthy and usably secure systems and appropriate privacy safeguards.
2. Accelerating Transition to Practice: Transition successful fundamental research results and innovations into early adoption and use, and allow 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.
3. Education and Preparation of Cybersecurity Researchers and Professionals: Increase the number of qualified American students who pursue degrees in cybersecurity and privacy and enhance the capacity of institutions of higher education to produce professionals in these fields to meet the needs of our increasingly technological society. This goal also includes NSF's investment in the CyberCorps®: Scholarship for Service (SFS) program, which supports cybersecurity education and workforce development.

FY 2020 Investments

Goal 1: Foundational Research

- NSF will issue a revised SaTC solicitation for FY 2020. SaTC will continue to fund innovative projects that advance the science of cybersecurity and privacy, with emphases on: sociotechnical aspects; "blue sky" approaches to security and privacy; artificial intelligence (AI) as a tool for cybersecurity; security of AI and machine learning (ML) systems, including adversarial ML; implications of quantum computing for security, including post-quantum cryptography; and architectures and technologies for protecting cyberspace from the ever-growing smart-and-connected commodity devices.
- NSF will issue a separate solicitation under the SaTC umbrella in FY 2020 for center-scale efforts that address "grand challenge" research areas in cybersecurity and privacy.
- NSF will build upon existing and develop new partnerships with other federal agencies, industry, and international organizations to more effectively achieve the SaTC program's long-term goals. Towards this end, NSF will support a Research Coordination Network (RCN) that focuses on fostering international collaborations between US-based researchers and their counterparts in other countries.
- NSF will pursue additional efforts to grow the cybersecurity research community to include more researchers who cross the boundaries between computer and information science and engineering, engineering, the social, behavioral, and economic sciences, mathematics, statistics, and education research. For example, NSF may issue a Dear Colleague Letter that will focus on bringing together computer and information scientists and engineers with social, behavioral, and economic scientists to enable early-stage, socio-technical advances in cybersecurity and privacy. In addition, NSF will hold workshops on a range of cutting-edge topics, including novel applications of blockchain, as well as security and privacy challenges in smart infrastructure, autonomous, and AI-based systems.

Goal 2: Accelerating Transition to Practice (TTP)

- SaTC will continue its focus on TTP research results ready for experimental deployment, early adoption, commercial innovation, and/or implementation in cyberinfrastructure through support of TTP-designated projects.
- In FY 2020, SaTC plans to fund an industry-academic RCN to foster stronger collaboration between academic researchers and industry.

Goal 3: Education and Preparation of Cybersecurity Researchers and Professionals

- SaTC will continue the focus on cybersecurity education in FY 2020, with the aim of creating and sustaining an unrivaled American cybersecurity workforce capable of developing secure cyberinfrastructure components and systems and raising the awareness of cybersecurity challenges across the entire American population.

- SFS will increase outreach to the K-12 community, supporting efforts such as summer camps and a cybersecurity element within NSF's K-12 computer science education portfolio.
- NSF will encourage and incentivize SFS institutions to participate in task forces on the cybersecurity workforce at the state level and explore possible private-public partnerships. SFS will include community colleges in the types of institutions eligible for awards.
- SFS will continue to support the GenCyber project on SFS campuses.

UNDERSTANDING THE BRAIN (UtB) **$123,360,000**

-$34,020,000 / -21.6%

UtB Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$45.56	-	$43.21
CISE	21.30	-	19.60
EHR	11.99	-	7.00
ENG	28.08	-	16.75
MPS	22.02	-	11.80
SBE	28.43	-	25.00
Total	**$157.38**	**-**	**$123.36**

Overview

UtB is a grand scientific challenge 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 2017 American Innovation and Competitiveness Act (PL 114-329).[1] Through several cross-cutting programs and numerous existing core programs, NSF will continue to support catalytic innovation and the establishment of a national research infrastructure that will accelerate 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 biophysical, molecular, physiological, and genetic to cognitive and behavioral, with the ultimate goals of establishing integrative, quantitative, 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, activity, and function. Since FY 2014, the UtB activity has consolidated NSF's ongoing activities in cognitive science, neuroscience, and the BRAIN Initiative. UtB will continue to run through FY 2020. 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 convergence of NSF's disciplinary and interdisciplinary fields is expected to foster new transdisciplinary and convergence approaches to transform understanding of brain, cognition, behavior, and education approaches, through the development of new theories and technologies.

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] www.congress.gov/bill/114th-congress/senate-bill/3084/text

1. Develop innovative neurotechnologies, new physical and conceptual 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 understanding of how the brain responds and adapts to changing environments; and
4. Train a new generation of scientists, engineers, and educators for a transdisciplinary, globally-competitive workforce in neuroscience and neuroengineering.

FY 2020 Investments

In FY 2020, NSF's total investment in the UtB activity is $123.36 million. Within this amount, $64.62 million will support activities related to the BRAIN Initiative. NSF will maintain the UtB focus by continuing to employ investment strategies designed to enable the transformational research, engineering, infrastructure (including cyberinfrastructure) development, and training required to accomplish the multi-year overall goals specified above. Using dedicated solicitations and existing mechanisms including, workshops, dear colleague letters (DCLs), Research Coordination Networks (RCNs), EArly-Concept Grants for Exploratory Research (EAGERs), Ideas Labs, and supplements to existing awards, NSF will continue to bring together the diverse relevant scientific communities in biology; chemistry; behavior and cognition; computer, computational, and information science; education; engineering; physics; psychology; mathematics; and statistics to identify scientific priorities and needed research infrastructure (including cyberinfrastructure), to 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 specialized programs: (1) the Collaborative Research in Computational Neuroscience (CRCNS) program, which is a cross-directorate, cross-agency [both NSF and National Institutes of Health (NIH)], multinational program that funds projects with the goal of providing a powerful modality for larger-scale interaction and collaborative discovery; (2) the Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS) program that supports research and innovation to enable large-scale aggregation, sharing, and open science driven by integrative neural and cognitive discovery; and (3) the Next Generation Networks for Neuroscience (NeuroNex) program that supports "Neurotechnology Hubs" and "Theory Teams" to develop and disseminate the newest technologies and theories to neuroscience researchers most able to capitalize on them for advancing 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 as described in NSF's DCL "National Brain Observatory: A Phased Approach for Developing a National Research Infrastructure for Neuroscience" (NSF 16-047).[2] While the NeuroNex program is focused primarily on priority areas 1 and 4 above, the CRCNS and NSF-NCS programs focus primarily on priority areas 2, 3 and 4. NSF is promoting work in educational neuroscience through the NSF-NCS program, noting that advances in neural systems can have significant implications for research on education, consistent with priority areas 2 and 3. Early outcomes of NSF-supported efforts include new international partners for NeuroNex in FY 2020 and a special issue of the journal *Neuron* highlighting the importance of neuro-ethics for neuroscience research, the first written from a global scale.[3]

The NSF-wide UtB Coordinating Group will continue to facilitate this cross-foundational activity with a particular focus on leveraging future investments with past investments made not only by NSF, but also by other agencies and foreign countries. The UtB Coordinating Group will also oversee the progress on scientific and programmatic activities to ensure that expected outcomes are being accomplished.

[2] www.nsf.gov/pubs/2016/nsf16047/nsf16047.jsp
[3] www.internationalbraininitiative.org/news/neuron-special-issue-neuroethics

IMPROVING UNDERGRADUATE STEM EDUCATION (IUSE) $93,130,000

-$5,990,000 / -6.0%

IUSE Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$2.23	-	$1.90
CISE	-	-	2.00
EHR	90.97	-	78.30
ENG	0.05	-	4.75
GEO	5.82	-	5.70
OPP	0.05	-	0.48
Total	**$99.12**	**-**	**$93.13**

Overview

High-quality undergraduate STEM education is essential for preparing a diverse professional STEM workforce that can sustain U.S. leadership in STEM innovation.[1,2] IUSE is an NSF-wide activity that works toward the goal of ensuring that every college student in the U.S. has exceptional STEM learning opportunities. To this end, IUSE supports research and development to improve undergraduate STEM education from individual STEM classrooms to nation-wide efforts. IUSE also supports innovations in undergraduate STEM education in emerging areas, such as those needed to produce a STEM workforce that can use innovative interdisciplinary approaches, massive data sets, and/or computation to identify and solve problems. All IUSE projects include research and assessment components, thus also contributing new knowledge about what works in undergraduate STEM education and why.

STEM undergraduate education is essential to meet the demand for STEM professionals in the U.S. workforce. Currently, STEM-related occupations represent about six percent of total U.S. employment[3] and the demand for workers in STEM-related occupations is expected to continue to grow at higher than average rates. The average wage of STEM occupations is nearly double that of non-STEM occupations.[4] In addition to educating STEM workers, high-quality undergraduate STEM education is essential for producing STEM-knowledgeable workers who can use STEM skills in business and industry, as well as a STEM-literate public that understands and benefits from the progress of STEM.[5]

Reflecting the breadth of STEM, IUSE is one of NSF's most flexible funding programs, capable of supporting projects relevant to any NSF directorate. IUSE also supports projects that cross all STEM

[1] Hulten, C. (2017). The Importance of Education and Skill Development for Economic Growth in the Information Era. In Education, Skills, and Technical Change: Implications for Future US GDP Growth. University of Chicago Press. Retrieved from: www.nber.org/chapters/c13937.pdf

[2] Olson, S., & Riordan, D. G. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. Executive Office of the President.; https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf.

[3] www.bls.gov/opub/ted/2017/8-point-8-million-science-technology-engineering-and-mathematics-stem-jobs-in-may-2016.htm?view_full

[4] www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf

[5] National Academies of Sciences, Engineering, and Medicine. (2016). Science literacy: Concepts, contexts, and consequences. National Academies Press. Retrieved from: www.nap.edu/catalog/23595/science-literacy-concepts-contexts-and-consequences

disciplines, such as incorporating active learning approaches.[6] The flexibility of IUSE enables it to respond rapidly to emerging areas and priorities. For example, in FY2018, it launched the Accelerating Discovery Program, which funded undergraduate education projects aligned with NSF's 10 Big Ideas, including efforts to establish the nation's first undergraduate program on quantum computing.

IUSE is a multi-year, NSF-wide priority investment area, spanning FY 2014 to FY 2020. However, NSF's emphasis on improving undergraduate STEM education is expected to extend beyond FY 2020, enabling NSF to support the ongoing improvements needed for undergraduate STEM education to remain current with innovations in STEM and STEM learning.

Goals

IUSE aims to contribute to nation-wide improvements in undergraduate STEM Education by:
1. Improving STEM learning and learning environments at the undergraduate level. These investments improve the knowledge base for innovative undergraduate STEM instruction.
2. Broadening participation and institutional capacity for STEM learning. These investments increase the number and diversity of undergraduate students in STEM majors and career pathways.
3. Building the STEM workforce for tomorrow. These investments improve the preparation of undergraduate students to be productive members of the future STEM and STEM-capable workforce.

FY 2020 Investments

As part of its mission to advance STEM, NSF plans to invest $93.13 million in FY 2020. This funding represents investments within and across directorates and is aligned with the IUSE goals. The IUSE initiative's anchor investment is IUSE: EHR, a solicitation-based program in the EHR Division of Undergraduate Education (DUE). IUSE: EHR funds: (1) innovative learning resources; (2) design of research questions to understand the impact of such resources; (3) strategies to implement effective instruction in a department or multiple departments, within or across institutions; (4) faculty development projects; (5) design and testing of instruments for measuring student outcomes; and (6) innovative activities that could have a high impact on learning and contribute to transforming undergraduate STEM education. IUSE: EHR is complemented by five additional IUSE core programs, which share the three common IUSE goals, but with a narrower funding focus than IUSE: EHR. These programs and their number of awards anticipated for FY 2020 are as follows:

- *EHR/IUSE: Hispanic Serving Institutions (HSI):* Supports improvements in retention and graduation rates at HSIs that have not received high levels of NSF support; approximately 15 awards.
- *BIO: Research Coordination Networks: Undergraduate Biology Education (RCN: UBE)*: Supports collaborative networks to improve undergraduate biology education; approximately 10 awards.
- *ENG: IUSE/Professional Formation of Engineers: Revolutionizing Engineering Departments (IUSE/PFE:RED):* Supports organizational change strategies to transform undergraduate engineering education; approximately 3 awards.
- *CISE: IUSE/Computing in Undergraduate Education (CUE):* Supports multi-institution teams to re-envision the role of computing in interdisciplinary fields and to integrate the study of ethics into computer science curricula; approximately 14 awards.
- *GEO/IUSE: Pathways into Geoscience (IUSE: GEOPATHS):* Support strategies to increase the number and diversity of undergraduate students pursuing geoscience degrees; approximately 20 awards.

[6] Freeman, S., et al. (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

MAJOR INVESTMENTS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) GRADUATE STUDENTS AND GRADUATE EDUCATION

Overview

A U.S. science, technology, engineering, and mathematics 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 collaborations that span institutions, disciplines, and national boundaries, and require the use of sophisticated data infrastructure, instruments, and networks of researchers. Computationally intensive and data-enabled science is dramatically changing the knowledge and experience required of researchers and other STEM professionals across all 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 and the private and public sectors.

Investing in discoverers—that is, building a diverse and talented next-generation of STEM research leaders and professionals across sectors through inclusive processes—is an important NSF focus. A major portion of NSF's overall investment in graduate education and graduate students supports research assistants funded through research grants. NSF also supports graduate students through other mechanisms such as fellowships and traineeships.

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 to participate and innovate in STEM intensive careers. This goal is based on the following framework[1] to:

- *Advance Science and Engineering Research:* Support graduate students and graduate education to enable long-term contributions of new knowledge at the frontiers of science and engineering.
- *Broaden Participation to Promote Excellence in Research and Build the Next Generation STEM Workforce***:** Recruit graduate students from a variety of geographic, demographic, social, and educational backgrounds to promote the advancement of science and a highly qualified professional workforce.
- *Build Effective Models of Graduate Education and Workforce Development:* Support the development and use of innovative models and evidence-based approaches in graduate education, including education and research about promising practices and program effectiveness.

FY 2020 Investments

NSF's two major agency-wide programs in graduate education are the Graduate Research Fellowship Program (GRFP) and the NSF Research Traineeship (NRT) program. EHR leads administration for both programs. NSF-wide working groups guide the management of these programs. Both programs contain design elements recommended in major national reports[2] as ways to better prepare graduates for a broad

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[1] National Science Foundation (2016). NSF Strategic Framework for Investments in Graduate Education. National Science Foundation, Alexandria, VA. Retrieved from: www.nsf.gov/pubs/2016/nsf16074/nsf16074.pdf.

[2] National Academy of Sciences, Engineering, and Medicine. 2018. Graduate STEM Education in the 21st Century. Washington, DC: The National Academies Press. Retrieved from: https://www.nap.edu/catalog/25038/graduate-stem-education-for-the-21st-century; 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-

range of careers. GRFP has identified and supported outstanding STEM researchers since 1952. The NRT program focuses on developing researchers in high priority interdisciplinary research areas. Both programs provide professional development opportunities for graduate students, including internships and international research experiences. Ongoing evaluation and monitoring of the programs and students involved in GRFP and NRT provide rich data that will be used for gaining a better understanding of graduate program experiences and interventions, monitoring career outcomes longitudinally, and contributing to improving the understanding of STEM professional workforce development.

There are several other programs at NSF that focus on developing sectors of the STEM workforce and provide support to students in testing new models and approaches to graduate education. For example, the CyberCorps®: Scholarship for Service (SFS) program, led by EHR, addresses the national need for a cybersecurity workforce. 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. The 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. This broad suite of programs contributes substantially to the NSF investment in graduate education of the STEM research and education workforce of the future.

<u>Graduate Research Fellowship Program</u>

The goal of GRFP is to help build the STEM human capital necessary to ensure the Nation's leadership in advancing innovations in S&E. GRFP selects, recognizes, and financially supports graduate students with demonstrated high potential for excellence in STEM careers. Applications are welcome from students in disciplines supported by NSF, including STEM, STEM education, or STEM interdisciplinary areas. In FY 2020, GRFP will be funded at $256.90 million. The resources will support 1,600 new fellows with a cost of education allowance of $12,000 and a stipend of $34,000. The GRFP program will continue to align awards with NSF research priorities such as big data, artificial intelligence, quantum information science, and NSF's 10 Big Ideas.

GRFP Funding by Account

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Education and Human Resources	$142.58	-	$128.45
Research and Related Activities	142.27	-	128.45
Total	**$284.85**	**-**	**$256.90**
Number of New Fellows	2,000		1,600
Projected Fellows on Tenure[1]	5,705		5,400

[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 or STEM education field.

<u>NSF Research Traineeship</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 innovative, effective, and scalable

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 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 with an emphasis on future scientific challenges, inclusion of both masters and doctoral students, a broader definition of trainees, and greater budgetary and programmatic flexibility. NRT addresses interdisciplinary graduate education through two approaches: traineeships and fundamental education research. Traineeships are dedicated to effective training of STEM graduate students in high-priority interdisciplinary research areas using a comprehensive training model that is innovative, evidence-based, and aligned with changing workforce and research needs. This training includes development of technical and professional skills for both research and research-related careers within and outside academia. Fundamental education research is addressed through the Innovations in Graduate Education (IGE) component of NRT, which focuses on test-bed projects aimed at piloting, testing, and validating innovative and potentially transformative approaches to graduate education, including activities such as career preparation, mentoring, partnerships, and internships. NSF expects to fund about 12-15 traineeships and up to $8.0 million in fundamental research in graduate education.

NRT Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$2.82	-	-
CISE	7.10	-	-
EHR	33.11	-	49.53
ENG	2.79	-	-
GEO	2.77	-	-
MPS	4.54	-	-
OPP	0.72	-	-
Total	**$53.85**	**-**	**$49.53**

In FY 2020, NRT funding is consolidated into EHR.

<u>CyberCorps®: Scholarship for Service</u>
The SFS program addresses cybersecurity education and workforce development by providing funding to institutions for awarding scholarships to undergraduate and graduate students in cybersecurity. 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.

SFS Funding
(Dollars in Millions)

FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
$55.09	-	$55.09

<u>Additional Programs and Activities Supporting STEM Graduate Education and Workforce Development</u>
Louis Stokes Alliances for Minority Participation-Bridge to the Doctorate (LSAMP-BD)
The LSAMP program assists universities and colleges in diversifying the STEM workforce by increasing the number of STEM baccalaureate and graduate degrees awarded to populations historically under-represented in STEM disciplines: African Americans, Alaska Natives, American Indians, Hispanic Americans, Native Hawaiians, and Native Pacific Islanders. The LSAMP program provides funding to alliances comprised of multiple degree-granting organizations that can implement comprehensive and

sustained strategies that result in the graduation of well-prepared, highly-qualified students from underrepresented groups. The LSAMP-BD is a targeted activity where established alliances provide post-baccalaureate fellowships to cohorts of students to obtain the necessary academic and research skills to successfully earn STEM doctoral degrees and transition to the STEM workforce. LSAMP-BD funding allows institutions to provide graduate 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.

NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)
NSF established the S-STEM program 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 2005. 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 low-income, academically talented U.S. students with demonstrable financial need to enter the STEM workforce or STEM graduate school following completion of an associate, baccalaureate, or graduate degree in STEM fields. The program emphasizes the importance of recruiting students to STEM disciplines, mentoring and supporting students through degree completion, and partnering with employers to facilitate student career placement in the STEM workforce. S-STEM provides individual scholarships of up to $10,000 per year, depending on financial need.

Robert Noyce Teacher Scholarship (Noyce)
The Noyce program seeks to encourage talented STEM majors and professionals to become K-12 mathematics and science teachers. Through the Noyce NSF Teaching Fellowship track, funding supports STEM professionals who enroll as NSF Teaching Fellows in master’s degree programs. The fellows are then able to earn teacher certification or licensing to teach a STEM discipline in an elementary or secondary school 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 are enrolled in a master’s degree program in their field. The fellows participate in mentoring and professional development activities to become highly effective master teachers and leaders. They are provided salary supplements while they fulfill a five-year teaching commitment in high-need school districts. The Noyce Teaching and Master Teaching track expects to fund about 120 fellows in FY 2020.

Additional Programs Supporting STEM Graduate Education and Workforce Development

(Dollars in Millions)

Program	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
LSAMP-BD	$16.13	-	$11.00
S-STEM	2.32	-	2.00
Noyce Teaching and Master Teaching Fellows	3.00	-	4.00
Total	**$21.45**	**-**	**$17.00**

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)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Centers for Analysis & Synthesis	$6.00	-	$4.80	-$1.20	-20.0%
Centers for Chemical Innovation	22.01	-	19.00	-3.01	-13.7%
Engineering Research Centers	68.49	-	54.66	-13.83	-20.2%
Materials Centers	46.40	-	54.00	7.60	16.4%
Science & Technology Centers	60.24	-	42.05	-18.19	-30.2%
Total	**$203.14**	**-**	**$174.51**	**-$28.63**	**-14.1%**

Description of Major Changes

Centers for Analysis and Synthesis - BIO
The FY 2020 Request of $4.80 million funds one Center for Analysis and Synthesis—the National Social-Environmental Synthesis Center (SESYNC).

SESYNC, located at the University of Maryland, is dedicated to accelerating scientific discovery at the interface of human and ecological systems. This center allows scientists from diverse disciplines to transform approaches for identifying solutions to society's most challenging and complex environmental problems. Workshops sponsored by this Center engage philosophers, sociologists, political scientists, psychologists, anthropologists, and environmental biologists (together with policy makers) to integrate broad disciplines from the outset and to set precedence for all subsequent activities. FY 2020 is the final year of the five-year renewal award and funding will provide continued support for staff and core research activities.

Centers for Chemical Innovation (CCI) - MPS
The FY 2020 Request of $19.0 million is expected to fund up to six Phase II CCIs, three continuing, one potential renewal, and up to two new centers.

CCIs accelerate the solution of fundamental chemical research challenges, produce transformative research that leads to innovation, and attract broad scientific and public interest. CCIs respond rapidly to emerging opportunities through enhanced collaborations as well as initiate high risk / high reward projects. CCIs integrate research, innovation, education, broadening participation, and informal science communication. Each CCI is focused on a chemistry challenge and assembles a multidisciplinary, multi-sector collaborative team. CCIs encompass synthesis, characterization, theory, modeling, data science and computation, along with training for students at all levels. CCIs are also actively engaged in knowledge transfer to industry and commercialization of their discoveries and new technologies.

Each year, CCIs include nearly 100 participating academic institutions, 65 non-academic partner institutions, and over 175 Senior Personnel, 100 Postdoctoral Associates, 255 Graduate Students, and 62

Undergraduate Students.

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). In FY 2020 three continuing Phase II CCIs and one potential renewal will be funded. Five Phase I CCIs started in FY 2017 will also be eligible to compete for Phase II in FY 2020, out of which up to two new Phase II CCIs may be funded. A Phase I CCI competition will be held in FY 2020, supporting up to three new developmental awards. Phase I awards are considered part of the NSF Division of Chemistry's core research program investments as they fall under the threshold for formal NSF center awards; thus, their funding is not captured here. The themes of the new Phase I CCI are varied and include the QL, URoL, and HDR Big Ideas, as well as sustainable chemical technologies, and other topics in advanced manufacturing.

An independent CCI evaluation was funded in FY 2017 and is expected to be completed in late calendar year 2019. This evaluation is intended to inform both internal management and external stakeholders about the effectiveness of the CCI program in meeting its core mission. The CCI Program is unique within NSF in that it offers a Phase I on ramp to the larger Phase II competition. Evaluation of this on-ramp is expected within the overall CCI evaluation.

<u>Engineering Research Centers (ERC) - ENG</u>
The FY 2020 Request is $54.66 million. This funding levels supports 17 NSF Engineering Research Centers. The total includes initial funding for three 4th-generation Engineering Research Centers that will advance convergent engineering research to tackle high-impact challenges and benefit U.S. security, prosperity, health and society. The new ERCs will implement new strategies for effective team formation and engagement with stakeholder communities to maximize their impacts.

All NSF ERCs enable innovation, combining the energy and intellectual curiosity of university research focused on discovery with real-world engineered systems and technology opportunities through partnerships with industry. Since the program began in 1985, ERC products of innovation include more than 2,400 inventions disclosures, 2,000 patent applications filed, 800 patents awarded, and 1,300 licenses. The centers also have a successful track record for educating a technology-enabled workforce with hands-on, real-world experience. Together, the NSF ERCs have graduated 4,284 Bachelor's, 4,159 Master's, and 4,790 Doctoral degree students and impacted a total of 68,000 K–12 teachers and students. The NSF ERCs are effective at broadening participation from underrepresented groups. For example, across currently active ERCs, women comprise approximately 32 percent of those involved in center activities, in comparison to the national average of 16 percent across engineering. In addition, the percentage of underrepresented minorities participating is more than double that of engineering's national average.

The ERC program periodically commissions studies by external evaluators to examine aspects of the program, such as the effectiveness of ERC graduates in industry and the benefits of ERC membership to industry. In FY 2015, NSF funded the National Academies of Sciences, Engineering, and Medicine to study the future of center-based, multidisciplinary engineering research. The study report, delivered May 2, 2017, articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research. After careful consideration, in FY 2018 ENG sparked new convergent engineering research collaborations through planning grants, providing 60 awards to build capacity for a new generation of engineering research centers. In October 2018 (NSF 19-503) ENG released a solicitation for the 4th generation of ERCs and anticipates awards in 2020.

The report[1] "Post-Graduation Status of Engineering Research Centers—2010" (SciTech Communications),

[1] http://erc-assoc.org/sites/default/files/topics/Grad_ERC_Report-Final.pdf

augmented by a recent update, found that 29 of the 35 centers (83 percent) that graduated after 10 years of NSF support are self-sustaining, with most NSF ERC features in place and strong financial support from other government sources and industry partners.

<u>Materials Centers - MPS</u>
This long-standing, flagship program will complete its triennial competition in FY 2020 and will fund up to nine new centers.

MRSECs exist as hubs to solve complex grand challenge materials problems requiring broad complementary multidisciplinary expertise within the physical sciences and engineering to understand materials phenomena, exploit materials behavior, and to create and discover new materials. Through collaborative efforts involving academics, industry, national laboratories experts, and international and educational partners, MRSECs are a primary example of what is known as transdisciplinary convergent research which typically includes synthesis, theory, characterization, evaluation, and application in interactive feedback loops.

MRSECs have five major components: (1) interdisciplinary research thrusts, (2) education and outreach, (3) industrial outreach/partnerships, (4) the materials research facilities network—providing access to more than 1,250 state-of-the art equipment instrumentation to materials researchers across the Nation—and (5) the SEED program which enables MRSECs to rapidly react/move into new high risk and potentially transformative areas not yet fully explored. Each year, MRSECs produce over 200 PhDs in STEM fields, mentor nearly 500 research experiences for undergraduate students and nearly 70 research experiences for teachers, and impact over 1 million students and parents through outreach activities such as summer camps, K-12 science curriculum development, K-12 in-school science demonstrations, development and deployment of science kits, and partnering with the Nation's top museums to create STEM-related exhibits that impact the public. Since 1994, the program has created over 161 startups and annually produces about 50 awarded patents and 30 patent licensures. MRSECs engage and assist about 250 industrial partners per year in advancing fundamental materials research that can be translated into the market place.

The FY 2020 Request of $54.0 million is expected to fund 17-18 Materials Research Science and Engineering Centers (MRSECs). FY 2019 will be spent preparing for the next MRSEC competition in FY 2020. This includes stimulating the seeding efforts built within each MRSEC to start addressing emerging research areas relevant to the Division of Materials Research. These areas include NSF's Big Ideas QL, FW-HTF, URoL, GCR, and HDR, as well as Materials Sustainable Development research. Informational sessions will take place at several university campuses across the country; potential university applicants will be attending these sessions.

<u>Science and Technology Centers: Integrative Partnerships (STC) - multi-directorate</u>
The FY 2020 Request of $42.05 million will support twelve existing STCs ($41.50 million) and the costs of STC program management and oversight ($550,000). The twelve existing STCs are continuing awards from the FY 2010, FY 2013, and FY 2016 cohorts. FY 2020 is the last year for providing ramped down funding for the five centers in the 2010 cohort. The competition for the FY 2021 cohort begins in FY 2019. Currently, full STC awards are for five years, with possible renewal for an additional five years, or 10 years total. The award sizes of the existing STCs are approximately $5.0 million per year with ramp down in years nine and ten.

The 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 include: engineering biological systems; energy-efficient electronics; new ways of handling the extraction, manipulation, and exchange of information; and new atomic scale imaging modalities. 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 workforce through intellectually challenging research experiences for students, postdoctoral fellows, researchers, and educators; they advance public scientific understanding through partnerships with K-12 and informal education communities. The knowledge transfer activities focus on engaging stakeholders with the intention of supporting innovation, providing key information to public policy-makers, and disseminating knowledge from one field of science to another. To inform NSF about the progress of individual centers and the program as a whole, the STC program has developed a network of evaluators working with the centers to share information and lessons learned about the most effective way to measure progress.

Estimates for Centers Participation in 2018

	Number of Participating Institutions	Number of Partners	Total FY 2018 NSF Support ($ in millions)	Total Leveraged Support ($ in millions)	Number of Participants
Centers for Analysis & Synthesis	397	133	$6.00	$0.74	877
Centers for Chemical Innovation	85	65	22.01	7.54	809
Engineering Research Centers	534	38	68.49	2.10	4,224
Materials Centers	326	253	46.40	51.40	4,410
Science & Technology Centers	190	221	60.24	27.60	2,650

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.

Centers Supported by NSF in FY 2018

Center	Institution	State
Centers for Analysis and Synthesis		
National Institute for Mathematical & Biological Synthesis	U of Tennessee	TN
CyVERSE (formerly iPlant)	U of Arizona	AZ
Socio-Environmental Synthesis Center	U of Maryland	MD
Centers for Chemical Innovation (Phase II awards only)[2]		
Center for Chemical Evolution	Georgia Institute of Tech	GA
Center for Chemical Innovation in Solar Fuels	California Institute of Tech	CA
Center for Chemistry at the Space-Time Limit	U of California-Irvine	CA
Center for Enabling New Technologies through Catalysis	U of Washington	WA
Center for Sustainable Materials Chemistry	Oregon State	OR
Center for Sustainable Nanotechnology	U of Wisconsin	WI
Center for Sustainable Polymers	U of Minnesota	MN
NSF Center for Aerosol Impacts on Chemistry and the Environment	U of California-San Diego	CA
NSF Center for Selective C-H Functionalization	Emory	GA
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	U of Tennessee	TN

[2] Smaller, developmental Phase I awards do not meet the criteria as formal NSF Centers and so are not captured here.

Transmission Network (CURENT)		
Engineering Research Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR)	Purdue	IN
Engineering Research Center for Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP)	Texas A&M	TX
Future Renewable Electric Energy Delivery and Management Systems (FREEDM)	North Carolina State	NC
Integrated Access Networks (CIAN)	U of Arizona	AZ
Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)	U of Texas	TX
Nanosystems Engineering Research Center for Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision (CELL-MET)	Boston College	MA
Nanotechnology Enabled-Water Treatment Systems (NEWT)	Rice University	TX
NSF Engineering Research Center for Cell Manufacturing Technologies (CMaT)	Georgia Institute of Tech	GA
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
Translational Applications of Nanoscale Multiferroic Systems (TANMS)	U of California-Los Angeles	CA
Materials Centers		
Brandeis Bioinspired Soft Materials Center	Brandeis	MA
Center for Dynamics and Control of Materials	U of Texas at Austin	TX
Center for Emergent Materials	Ohio State	OH
Center for Multifunctional Materials	Northwestern	IL
Center for Nanoscale Science	Pennsylvania State	PA
Center for Polarization and Spin Phenomena in Nanoferroic Structures	U of Nebraska	NE
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
Illinois Materials Research Center	U of Illinois at Urbana-Champaign	IL
Laboratory for Research on the Structure of Matter	U of Pennsylvania	PA
Materials Research Science and Engineering Center 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
Soft Materials Research Center	U of Colorado	CO
UW Molecular Engineering Materials Center	U of Washington	WA
Wisconsin Materials Research Center	U of Wisconsin	WI
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 NSF's 10 Big Ideas, SaTC, INFEWS, and UtB. Additional cross-cutting programs at NSF are selected for presentation in the narrative below. Full funding data for these programs are provided in the Summary Tables chapter.

ADVANCE

In FY 2020, $18.0 million in funding is requested for the ADVANCE program to encourage institutions of higher education and the broader science, technology, engineering and mathematics (STEM) community, including professional societies and other STEM-related not-for-profit organizations, to address various aspects of STEM academic culture and institutional structure that may differentially affect women faculty and academic administrators. As such, ADVANCE is an integral part of the NSF's multifaceted strategy to broaden participation in the STEM workforce and supports the critical role of the Foundation in advancing the status of women in academic science and engineering. Funding for ADVANCE in FY 2020 is consolidated into the EHR account, but the program will continue to fund projects in all areas of STEM supported by NSF.

Faculty Early Career Development (CAREER)

The CAREER program offers NSF's most prestigious awards in support of early-career faculty and is designed to provide stable support at a sufficient level and duration to enable awardees to develop careers not only as outstanding researchers but also as educators demonstrating commitment to teaching, learning, and dissemination of knowledge. The FY 2020 Request provides $249.14 million for the CAREER program, funding approximately 446 new CAREER awards, which support exceptionally promising college and university junior faculty who are committed to the integration of research and education and who are most likely to become the leaders in their fields. Funding for CAREER is provided by BIO, CISE, ENG, GEO, MPS, and SBE.

Long-Term Ecological Research (LTER)

The FY 2020 Request provides $28.43 million for LTER. LTER supports fundamental research that requires data collection over long time periods, to unravel the principles and processes of ecological science, which frequently involves long-lived species, legacy influences, and rare events. 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 2020 will be used to sustain site-specific research activities examining ecological and evolutionary dynamics in natural populations, communities, and ecosystems, some of which 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 and GEO.

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 Multi-User Research Facilities chapter.

Research Experiences for Undergraduates (REU)

In FY 2020, $76.37 million in funding is requested for the REU Sites and Supplements program. 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 2020 Request for NSF's RDE program totals $6.50 million. The RDE activity helps increase participation in STEM for postsecondary students with disabilities. 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's Division on Research on Learning in Formal and Informal Settings, with additional funding provided by MPS, SBE, and EHR's Divisions of Human Resource Development and Undergraduate Education for meritorious projects relevant their communities.

Research in Undergraduate Institutions (RUI)

The FY 2020 Request for NSF's RUI program totals $34.49 million. 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, MPS, and SBE.

NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

Total Funding for NNI

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$42.50	-	$42.50
CISE	15.68	-	14.05
EHR	3.20	-	2.50
ENG	206.00	-	168.50
MPS	300.14	-	161.84
SBE	0.40	-	-
IA	0.10	-	-
Total	**$568.02**	**-**	**$389.39**

Overview

NSF's contribution to the multiagency 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; quantum qubits and systems; nanosensors to monitor health, the environment, and human-machine interactions; 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 2019.[1] Funding by PCA is shown at the end of this discussion. Funding for the Nanotechnology Signature Initiative (NSI) on Nanotechnology Knowledge Infrastructure will continue through the end of FY 2019, without additional funding for FY 2020.

FY 2020 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 in areas of atomic and molecular research in 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 2020.

Overall, NSF's total NNI funding in the FY 2020 Request is $389.39 million. Several new directions planned for FY 2020 are nanotechnology for brain-like computing and advancing human-technology frontier, including highly energy efficient systems and intelligent cognitive assistants; nanobiomanufacturing, including nanobiomotors and cell technology; food-energy-water processes, such as nanofiltration at end-users; nanomodular materials and systems by design, including quantum structures and three-dimensional nanoscale materials; and emerging aspects of nanoelectronics, photonics, use of

[1] www.nano.gov

artificial intelligence for smart materials and systems, and neuroscience. NSF sponsors an annual NSE grantee conference to assess the progress in nanotechnology and facilitate identification of new research directions.[2]

In FY 2020, 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); 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. NSF will strengthen partnerships of new Nanoscale Engineering Research Centers (NERCs) with small businesses in the areas of nanomanufacturing and commercialization, and support an industrial internship program (INTERN) in emerging areas. NSF continues its contributions to translational innovation programs, including Grant Opportunities for Academic Liaison with Industry (GOALI); Industry-University Cooperative Research Centers (IUCRC); 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 10 Big Ideas, and particularly with QL, URoL, FW-HTF, HDR, and GCR.

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*,[3] which provides a vision of the field to 2020 and beyond. With the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), Office of Naval Research (ONR), and the U.S. Department of Agriculture (USDA), NSF co-sponsored the study entitled *Converging Knowledge, Technology, and Society*[4] evaluating the convergence of nanotechnology with other emerging areas by 2030. Other 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.[5,6,7]

PCAs are the major subject areas of relevance to the NNI agencies, where progress is critical to achieving NNI's goals and to realizing its vision.[8] NSF supports funding in all five PCAs.

<u>PCA 1: Nanotechnology Signature Initiatives (NSIs) and Grand Challenges (GCs)</u>

The first PCA, which encompasses the five—four, beginning in FY 2020—Nanotechnology Signature Initiatives (NSIs) and Grand Challenge, will be funded at a total of $91.50 million. The Water Sustainability through Nanotechnology NSI began in FY 2016 and will continue in FY 2020. The Nanotechnology-Inspired Grand Challenge for Future Computing began in FY 2017. Special emphasis will be on:

- Sustainable Nanomanufacturing ($28.0 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

[2] 2018 Nanoscale Science and Engineering Grantees Conference: www.nsf.gov/nano and www.nseresearch.org/2018/
[3] NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/
[4] NSF/WTEC 2013, Springer, available on www.nsf.gov/nano and www.wtec.org/NBIC2-Report/
[5] www.nsf.gov/nano
[6] 1.usa.gov/1Fg90Dw; www.src.org/nri/energy-efficient-computing-workshop.pdf
[7] www.semiconductors.org/issues/research/research/
[8] www.nano.gov/about-nni/what/vision-goals

structural carbon-based nanomaterials, optical metamaterials, cellulosic nanomaterials, nanobiomanufacturing and nanomodular systems. A Dear Colleague Letter, *Advanced Manufacturing Research to Address Basic Research Enabling Innovation at Manufacturing USA Institutes*, is planned for 2020. Engineering biology at the nanoscale for advanced manufacturing activities in BIO, ENG, and MPS are being organized for 2020. Methods for nanomanufacturing design are in synergy with the Materials Genome Initiative. A new direction is manufacturing of nanomachines and nanobiostructures.

- Nanoelectronics for 2020 and Beyond ($32.0 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 2020 with a focus on *Energy-Efficient Devices, Systems and Architectures (E2CDA)*. NSF will increase coordinated research on QL and the FW-HTF.
- Nanotechnology for Sensors and Sensors for Nanotechnology ($7.50 million)**—**This initiative funds the 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 in order 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 ENG's Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) will support this effort.
- Water Sustainability through Nanotechnology ($11.0 million)**—**This initiative 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 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. NSF will increase coordinated research on the FW-HTF.
- Nanotechnology-Inspired Grand Challenge for Future Computing ($13.0 million)**—**Research is planned on the NNI Grand Challenge related research on "Brain-like Computing" and "Intelligent Cognitive Assistants" (ICA). Two examples of active centers are the Science and Technology Center (STC) on Integrated Quantum Materials 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 plans to sponsor research on ICA as part of program announcements for two NSF Big Ideas: FW-HTF and GCR. Further collaboration is planned with industry groups developing hardware (with a focus on a "beyond Moore" system architecture and corresponding devices), software (with a focus on artificial intelligence), and implementing in various applications. The research will be conducted in collaboration with other agencies (NIH, Defense Advanced Research Projects Agency (DARPA)).

<u>PCA 2: Foundational Research</u>

The FY 2020 Request includes $207.47 million for the discovery and development of fundamental knowledge pertaining to new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale. Also included is funding for research aiming to understand scientific and engineering principles related to nanoscale systems, structures, processes, and mechanisms; research on the discovery and synthesis of novel nanoscale and nanostructured materials including biomaterials and modular structures; and research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, ethical, and legal implications. It will support activities surrounding the fundamental, interconnected elements of collaborative modeling and computer simulation, an interacting cyber-toolbox, and data infrastructure for nanotechnology. The Network for Computational Nanotechnology (NCN) conducts key activities in support to this PCA with about 1.4 million users per year and has been awarded an extension to 2022. About 60 percent of the MRSECs pursue NSE-related fundamental research.

PCA 3: Nanotechnology-Enabled Applications, Devices, and Systems
The FY 2020 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, 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 2020 Request includes $41.97 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 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. The FY 2020 Request for this is funded at $11.0 million. Other STC, ERC, and MRSECs have a focus supporting NNI such as the STC Center for Cellular Construction at the University of California-San Francisco (annual award since 2016 is approximately $5 million) and two NERCs, one each on nano-bio 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 competition "Generation Nano" Communication Competition sponsored by ENG, MPS and NSF's Office of Legislative and Public Affairs." and "Quantum Matters" Communication Competition" for undergraduate and graduate students[9], both nation-wide, with the participation of the Boston Museum of Science. NSF will increase coordinated research on Mid-Scale Research Infrastructure.

PCA 5: Environment, Health, and Safety
In FY 2020, NSF will continue its funding for the Environment, Health, and Safety (EHS) PCA at $10.55 million, representing roughly three 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. ENG's Nano EHS Program has changed to *Biological and Environmental Interactions of Nanoscale Materials*.

Coordination with Other Agencies

NSF's NNI program is coordinated with 28 departments and agencies through the National Science and Technology Council 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:

[9] www.mos.org/quantum-matters-competition

- Sustainable Nanomanufacturing—NSF, 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 NIST, Air Force Office of Scientific Research (AFOSR), DARPA, and SRC will continue in 2020 with a focus on "E2CDA" and "Brain-like Computing" and "Intelligent Cognitive Assistant";
- Nanoelectronics—NSF, NIST, Department of Defense (DOD), DOE, Intelligence Community (IC)/Director of National Intelligence (DNI), and NASA;
- ICA—NSF, SRC, SIA, and other semiconductor, software, social media and application industry groups;
- NNCI and NCN centers and networks—NSF, DOD, NASA, DOE, and NIH;
- Nanosensors—NSF, NIOSH, NIH, FDA, NIST, DOD, NASA, and EPA;
- INFEWS program—NSF and USDA/NIFA joint solicitation;
- NSF collaboration with NIOSH, NIH's National Cancer Institute (NCI), 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.
- 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request
1. Nanotechnology Signature Initiatives	$167.69	-	$91.50
Sustainable Nanomanufacturing	*35.89*	-	*28.00*
Nanoelectronics for 2020 and Beyond	*74.45*	-	*32.00*
Nanotechnology Knowledge Infrastructure	*20.21*	-	-
Nanotechnology for Sensors	*14.15*	-	*7.50*
Water Sustainability through Nanotechnology	*11.59*	-	*11.00*
Nanotechnology-Inspired Grand Challenge for Future Computing	*11.40*	-	*13.00*
2. Foundational Research	292.31	-	207.47
3. Nanotechnology-Enabled Applications, Devices, and Systems	49.91	-	37.90
4. Research Infrastructure and Instrumentation	45.56	-	41.97
5. Environment, Health, and Safety	12.54	-	10.55
Total	**$568.02**	**-**	**$389.39**

NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$93.50	-	$79.00
CISE	960.80	-	883.04
EHR	9.50	-	9.50
ENG	32.59	-	33.35
GEO	24.00	-	20.00
MPS	152.34	-	149.47
SBE	22.84	-	22.97
Total	**$1,295.57**	**-**	**$1,197.33**

Overview

NSF is a primary supporter of the NITRD program, and NSF's NITRD portfolio includes all research, research infrastructure, and education investments in CISE, as well as contributions from all other directorates across the agency, enabling investments in every NITRD Program Component Area (PCA). The NSF assistant director for CISE is co-chair of the NITRD Subcommittee of the National Science and Technology Council's Committee on the Science and Technology Enterprise. In addition, numerous NSF staff work in close collaboration with other NITRD agencies and participate in all NITRD Interagency Working Groups, including at the co-chair level in most.

NSF's FY 2020 Budget Request includes support for NITRD at a level of $1,197.33 million. NITRD activities represent approximately 17 percent of NSF's FY 2020 Budget Request to Congress. CISE's support comprises 74 percent of NSF's NITRD activities.

The PCAs are reviewed annually to ensure they remain relevant and reflect the most up-to-date R&D needs of the Nation. For FY 2020, the Artificial Intelligence (AI) R&D PCA was added to support the Administration's goal of being a world leader in the development of transformative AI technologies. AI-related programs that have primary emphases other than AI are reported in other PCAs. The definition of the Computing-Enabled Human Interaction, Communication, and Augmentation (CHuman) PCA was updated to remove overlaps with the new AI PCA and to focus on group and collaborative systems, tools, and studies rather than on individuals. The definition of the Software Productivity, Sustainability, and Quality (SPSQ) PCA was updated to better reflect the current state of software research.

FY 2020 NSF Investments by Program Component Area (PCA)

The following information focuses on FY 2020 NSF investments, both new and continuing, by PCA.

<u>AI R&D ($193.88 million):</u> A key focal point of the increased investment in AI R&D will be support for *AI Frontiers*, a new center-scale activity that will span (a) foundational areas of machine learning (ML), computer vision, natural language processing, and autonomy, along with safety, security, robustness, and explainability of AI systems; (b) translational research at the intersection of AI and various science and engineering domains supported by NSF as well as sectors such as agriculture, transportation, and personalized medicine; (c) workforce development, including growing human capital and institutional

capacity to nurture a next generation of AI researchers and practitioners; and (d) advanced computing infrastructure, including access to data and compute capabilities enabling AI innovations.

AI will also support HDR through research investments in real-time sensing, learning, and decision making. Additionally, it will include ENG investments in advanced manufacturing and the mind, machine, and motor nexus; SBE investments to integrate machine learning advances with learning mechanisms developed in cognitive science, develop new statistical inferences and algorithms for the analysis of large data sets, and understand the legal and ethical implications of AI; BIO investments in ML, natural language processing, computer vision, and genetic algorithms applied to solve problems such as genome sequence alignment, prediction of protein structure, reconstruction of evolutionary relationships, and extraction of quantitative information from multi-media data sources; and MPS investments in ML, deep learning, and neural networks through the Condensed Matter and Materials Theory, Designing Materials to Revolutionize and Engineer our Future, and Materials Research Science and Engineering Centers programs.

<u>CHuman ($77.16 million):</u> CHuman will include investment in FW-HTF, which supports convergent research to understand and develop the human-technology partnership, design new technologies to augment human performance, illuminate the emerging socio-technological landscape, and foster lifelong and pervasive learning with technology. As part of FW-HTF, CHuman will also include investment in the Cyberlearning for Work at the Human-Technology Frontier program, which will respond to the pressing societal need to educate and re-educate learners of all ages (American students, teachers, and workers) in STEM content areas so that they are equipped with the skills required for future jobs. CHuman will also include SBE investment on cyberinfrastructure related to its three major ongoing social science 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.

<u>Computing-Enabled Networked Physical Systems (CNPS) ($62.35 million):</u> CNPS will include CISE and ENG investments in Cyber-Physical Systems (CPS), enabling foundational interdisciplinary research and education in adaptive and pervasive smart systems supporting applications such as the smart grid, intelligent transportation systems, and medical devices. It will also include investment in the NSF-wide Smart and Connected Communities (S&CC) program, which will support interdisciplinary, integrative research that deeply engages local residents, stakeholders, and governments to improve understanding, design, and long-term sustainability of intelligent infrastructure for American communities, thereby leading to enhanced quality of life for residents. CNPS will additionally include BIO investment in expanding and enhancing access to the national resource of digital biological and paleontological data and ENG investment in advanced manufacturing, including cyber-manufacturing.

<u>Cyber Security and Privacy (CSP) ($96.20 million):</u> CSP will include investment in the NSF-wide SaTC program and other related cybersecurity and privacy research. The investment in SaTC in particular 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.

<u>Education and Workforce (EdW) ($55.70 million):</u> EdW will include CISE and EHR investments in IUSE: Computing in Undergraduate Education (CUE), to support efforts to re-envision the role of computing in interdisciplinary collaboration within American institutions of higher education and in Computer Science for All: Researcher-Practitioner Partnerships (CSforAll: RPPs), to support the R&D needed to bring computer science and computational thinking to all schools at the preK-12 levels. It will also include CISE and EHR investments supporting workforce development in cybersecurity, enabling a growing pipeline of researchers, educators, and practitioners, and allowing all Americans to understand the security and privacy of the digital systems on which their lives increasingly depend. EdW will additionally include BIO

investment in advancing America's ability to incorporate and apply biological knowledge to economic development and other issues of societal importance.

Enabling-R&D for High-Capability Computing Systems (EHCS) ($159.30 million): EHCS will include investments in strategic computing activities previously initiated under the National Strategic Computing Initiative, which will support research advances in new computing technologies, architectures, and platforms for the future, as well as the development of advanced computing systems and services, including maximizing the benefits of these systems and services through deep integration with science and engineering research. EHCS will also include MPS investment that advances computational algorithms and data analytics to address scientific and engineering challenges presented by data emerging from digital and observational data sources. It will also include MPS investment in fundamental research on innovative materials integration and novel phenomena associated with quantum information science, optical computing, and neuro-computing.

High-Capability Computing Infrastructure and Applications (HCIA) ($160.50 million): HCIA will include CISE investments on the development of software and algorithms for advanced computing systems and services. For example, HCIA will 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 programs such as Computational and Data-Enabled Science and Engineering; CISE and GEO investment in EarthCube, a cyberinfrastructure investment for the geosciences; GEO investment in the operations and maintenance of the National Center for Atmospheric Research's Wyoming Supercomputer facility and associated modeling efforts; and BIO investment in the application of advanced computing to a range of grand challenge problems in the biological sciences, including UtB, the genotype-to-phenotype relationship, and the environmental sciences.

Intelligent Robotics and Autonomous Systems (IRAS) ($36.01 million): IRAS will include CISE and ENG investments in robotics and autonomous systems, including 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.

Large-Scale Data Management and Analysis (LSDMA) ($173.36 million): LSDMA will include investment in HDR, including foundational research in data science and engineering; the development of a cohesive, federated approach to the research data infrastructure; and development of a 21st-century data-capable workforce. As part of HDR, LSDMA will include investment in the development of a comprehensive, scalable data infrastructure via the NSF-wide Cyberinfrastructure for Sustained Scientific Innovation (CSSI) program and the Computational and Data-Enabled Science and Engineering (CDS&E) program.

LSDMA will also include ENG investment on cyberinfrastructure for the Natural Hazards Engineering Research Infrastructure, which provides access to and storage and analysis of massive amounts of data related to natural disasters; MPS investments in Data-Driven Discovery Science in Chemistry as well as Computational Mathematics; SBE investments in data science and associated research infrastructure; and BIO investment in integrative modeling of complex biological processes.

Large-Scale Networking (LSN) ($117.25 million): LSN will include CISE investment on a set of Platforms for Advanced Wireless Research that enable research on topics ranging from dynamic spectrum sharing to measurement and monitoring, thus advancing the next generation of high-performance, robust wireless networks. LSN will also include a portion of CISE's investment in the NSF-wide S&CC program.

SPSQ ($65.62 million): SPSQ will include investment in the software foundations within CISE, as well as new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable through the NSF-wide CSSI program. SPSQ will also include investment in NSF-wide programs, such as the interagency and international Collaborative Research in Computational Neuroscience (CRCNS). For example, through CRCNS, BIO will fund research involving the development of software and other computational tools to advance biological knowledge and computational innovations.

NITRD Funding by Program Component Area
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Artificial Intelligence R&D	$184.51	-	$193.88
Computing-Enabled Human Interaction, Communications, Augmentation	104.85	-	77.16
Computing-Enabled Networked Physical Systems	67.72	-	62.35
Cyber Security and Privacy	103.99	-	96.20
Education and Workforce	75.51	-	55.70
Enabling-R&D for High-Capability Computing Systems	178.17	-	159.30
High Capability Computing Infrastructure and Applications	177.84	-	160.50
Intelligent Robotics and Autonomous Systems	38.21	-	36.01
Large-Scale Data Management and Analysis	167.16	-	173.36
Large Scale Networking	128.05	-	117.25
Software Productivity, Sustainability and Quality	69.56	-	65.62
Total	**$1,295.57**	**-**	**$1,197.33**

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Total Funding for USGCRP
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
BIO	$94.00	-	$87.60
GEO	130.00	-	113.00
SBE	14.98	-	12.46
OPP	15.15	-	11.04
Total	**$254.13**	**-**	**$224.10**

Overview

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. 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.

NSF has been investing in the fundamental research at the heart of global change issues for several decades. 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. The results of NSF investments have helped communities address challenges associated with mitigation, adaptation, and other responses to a changing and variable environment.

NSF funding for USGCRP in the FY 2020 Request is $224.10 million. NSF's investments will continue to support research that contributes to the USGCRP Goal Areas to (1) advance scientific knowledge of the integrated natural and human components of the Earth system and (2) inform decisions by providing the scientific basis to inform and enable timely decisions on adaptation and mitigation. In FY 2020, 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 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.

Past investments have helped inform the National Climate Assessment and several other technical reports mandated by the Global Climate Research Act of 1990. Investments have also aided U.S. communities to develop mitigation and adaptation strategies to address both challenges and opportunities derived from a changing environment. The fundamental knowledge gained through NSF disciplinary and cross-cutting programs focusing on the coupled natural-human system are critical in developing effective solutions to these challenges and opportunities.

FY 2020 Investments by Program Component Area (PCA)

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 PCA 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: NSF contributes to the Integrated Observations PCA 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 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.

Integrated Modeling: NSF will continue to devote significant resources to advancing climate modeling capabilities from global and centennial to regional and decadal scales. 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. 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 inform 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. In addition to supporting research that will inform adaptation decisions, NSF will also 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 2018 Actual	FY 2019 (TBD)	FY 2020 Request
Integrated Observations	$90.00	-	$83.24
Multidisciplinary Earth and Human System Understanding	121.60	-	103.74
Integrated Modeling	28.78	-	25.89
Science of Adaptation and Science to Inform Adaptation Decisions	13.75	-	11.23
Total	**$254.13**	**-**	**$224.10**

PERFORMANCE

NSF PERFORMANCE FRAMEWORK

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 2020 Annual Performance Plan (APP), Major Management Challenges, FY 2018 Annual Performance Report (APR), and Strategic Objective Progress Update. Information about NSF's performance can also be found on the NSF website in the FY 2018 Performance and Financial Highlights Report.[1]

Strategic Plan and Strategic Objectives

In FY 2018, NSF released a new Strategic Plan for FYs 2018-2022: *Building the Future: Investing in Discovery and Innovation.*[1] This Plan lays out two strategic goals that embody the dual nature of NSF's mission to advance the progress of science while benefitting the Nation: *Expand knowledge in science, engineering, and learning* and *Advance the capability of the Nation to meet current and future challenges*. A third goal, *Enhance NSF's performance of its mission*, directs NSF to hold itself accountable for achieving excellence in carrying out its mission. Each goal has two Strategic Objectives which together encompass all areas of agency activity. This goal structure enables NSF to link its investments to longer-term outcomes.

Strategic Goal		Strategic Objective
1	Expand knowledge in science, engineering, and learning.	**1.1 Knowledge** Advance knowledge through investments in ideas, people, and infrastructure.
		1.2 Practice Advance the practice of research.
2	Advance the capability of the Nation to meet current and future challenges.	**2.1 Societal Impacts** Support research and promote partnerships to accelerate innovation and to provide new capabilities to meet pressing societal needs.
		2.2 STEM Workforce Foster the growth of a more capable and diverse research workforce and advance the scientific and innovation skills of the Nation.
3	Enhance NSF's performance of its mission.	**3.1 Human Capital** Attract, retain, and empower a talented and diverse workforce.
		3.2 Processes and Operations Continually improve agency operations.

FY 2020 Performance Plan and Renewing NSF

NSF's FY 2020 APP includes two goals aimed at maintaining and improving customer service: NSF's longstanding performance goal to make timely award decisions and a goal, which was new in FY 2018, that focuses on improving the quality of the reviews written by outside reviewers. The APP also continues two goals aimed at monitoring of key program and infrastructure investments. Monitoring of activities funded as Mid-scale Research Infrastructure supported by the MREFC account has been added to the infrastructure investment monitoring goal. NSF will also have one or more new Agency Priority Goals (APG) in FY 2020, covering the time period of FY 2020-FY 2021. These will be defined in FY 2019 and the first quarter of FY 2020, and published in early calendar year 2020 on performance.gov and in the FY 2021 NSF Request to Congress.

For the second year, NSF's APP supports the Renewing NSF effort, the agency-wide change initiative that arose from NSF's internal work over the summer of 2017 to implement agency reform per M-17-22. NSF

[1] www.nsf.gov/about/performance

wrote Renewing NSF into its annual performance plans beginning in FY 2019: the FY 2018-2019 APG to Expand Public and Private Partnerships supports one of the four pillars of Renewing NSF, and the existing goals in the Performance Plan that monitor inclusion, human resources, and information technology customer service were refocused to support Renewing NSF efforts in Workforce and IT.

FY 2018 STRATEGIC OBJECTIVE PROGRESS UPDATES

In FY 2018, the National Science Foundation conducted Strategic Reviews (SRs) of the six Strategic Objectives in its 2018-2022 Strategic Plan, in response to the requirement of the GPRA Modernization Act 2010 Section 1116(f). Table 1 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.

Topic Selection and Conduct of the Strategic Review

In FY 2018, NSF developed topics by following the 2017 recommendation to apply strategic review methods more broadly to decision-making. Five cross-cutting issues, where the traditional directorate-based decision-making framework was likely to prove infeasible, were identified and mapped to NSF's six Strategic Objectives, new in FY 2018 under the new Strategic Plan. All were in response to larger administration activities which the Foundation was seeking to implement constructively and with minimal burden. Four arose from the agency reform effort, internally named Renewing NSF: workforce management, information technology, partnerships, and internal process improvements. The fifth SR developed out of NSF's efforts to use learning agendas to guide evidence-based policymaking.

The four Renewing NSF teams received the same charge: to assess the current status of the area, to develop a vision for their area, to relate it back to the larger Renewing NSF vision, and to identify next steps. A carefully facilitated Strategic Visioning process was used to accomplish this charge, to help teams define a compelling and collaborative vision of the future and a broad but flexible strategy for achieving that vision. The Learning Agenda SR also followed a facilitated process, in which the NSF INCLUDES program management team reflected on its prior actions and considered how having a Learning Agenda would have contributed to decision-making at each step of the program's lifecycle. Both approaches prioritized participatory decision-making, engaging dozens of participants in a novel collaborative approach to institutional learning and transformation.

Results and Follow-Up

All of the SRs generated broad suggestions for potential paths forward over the life of the new Strategic Plan. The Renewing NSF teams, instead of a focus on answering questions and developing prioritized recommendations, used the SR to articulate a vision for the future and suggest bold steps that could turn that vision into a reality. These visions and bold steps were used to generate widespread agency buy-in, first among leadership and then among agency staff, in a process of engagements in the summer and fall of 2018. Due to its more focused scope, the Learning Agenda SR team made recommendations for particular actions regarding using evidence to evaluate and inform programmatic decisions, practices that were reinforced by the eventual passage of the Foundations for Evidence-Based Policymaking Act.

NSF's Performance Improvement Officer (PIO) determined rankings by assessing the maturation stage of each SR's implementation plans. Since the strategic reviews concluded in the summer of 2018, multiple mechanisms for agency engagement and collection of feedback on the possible ways forward have been implemented.

Table 1. NSF's 2018 Strategic Reviews results summary, rankings, and progress updates.

Strategic Objective and Ranking	Summary of Strategic Review Findings	Progress Update as of Spring 2019
Objective 1.1 Knowledge Advance knowledge through investments in ideas, people, and infrastructure. **Objective 1.2 Practice** Advance the practice of research. ***Not Ranked***	**Focus area: Renewing NSF: Streamlining, standardizing, and simplifying processes and practices (S3).** In this team's vision, scientific discoveries and discoverers are catalyzed and enabled by S3 processes and practices. The four components to this vision are: • Priorities must reflect NSF values: Flexibility, Efficiency, Quality and Accuracy, Effectiveness, Inclusion, Focus on Mission; • Evidence-based improvement becomes the NSF culture, leading to a dynamic, adaptive organization; • S3 will yield time for higher impact work; and • S3 must be achieved through, with and for NSF staff.	Motivated by the SR, NSF is exploring ways to prioritize and distribute grantmaking workload across the fiscal year. Two automation projects were chosen to demonstrate short-term, high-yield progress: internal document clearance and compliance checking of incoming proposals against published criteria.
Objective 2.1 Societal Impacts Support research and promote partnerships to accelerate innovation and to provide new capabilities to meet pressing societal needs. ***Ranked as Noteworthy Progress***	**Focus area: Renewing NSF: Expanding and deepening public and private partnerships.** NSF envisions expanding partnerships to enhance the impact of its investments and contribute to American economic competitiveness and security. There are three components to this vision: • A unified strategic vision to guide proactive identification and pursuit of partnerships that advance NSF's mission; • Streamlined, flexible processes and tools for implementing a range of different types of partnerships, along with mechanisms for sharing knowledge and expertise; and • Systematic and continual evidence-based improvement of costs and benefits of partnerships, through evidence-based assessment.	The SR determined that a "partnerships toolkit" would be useful. The Partnerships Agency Priority Goal team is developing an "MoU Builder" tool, which would use pre-approved language and the answers to a set of standard questions to produce draft MoUs and focus the approval process on any non-standard areas. The APG team is also developing and testing a set of guiding questions to be asked early in the Partnership development process, which would ensure strategic alignment between NSF and its partners.

Strategic Objective and Ranking	Summary of Strategic Review Findings	Progress Update as of Spring 2019
Objective 2.2 STEM Workforce Foster the growth of a more capable and diverse research workforce and advance the scientific and innovation skills of the Nation. ***Not Ranked***	**Focus area: SR of NSF INCLUDES to illustrate a Learning Agenda.** The SR team found that the Learning Agenda process, appropriately adapted, can support an overarching vision of NSF as a learning organization where policies and decisions are informed by evidence. It made three recommendations: 1. Provide infrastructure, tools, capacity, and resources for organizational learning. 2. Provide incentives for contributing to organizational learning. 3. Build organizational learning into the way we do our work.	OIA’s Evaluation and Assessment Capability section (EAC) co-led this SR in response to the Commission on Evidence-Based Policymaking’s recommendation to “Develop ‘learning agendas’ to identify evidence-building priorities and needs.” EAC is spearheading pilot projects to inform implementation of the requirements of the Foundations for Evidence-Based Policymaking Act, which includes a mandate to establish and maintain Learning Agendas.
Objective 3.1 Human Capital Attract, retain, and empower a talented and diverse workforce. ***Ranked as Noteworthy Area for Improvement***	**Focus area: Renewing NSF: Adapting NSF’s work and workforce.** To ensure NSF has a workforce skilled to meet the needs of the future, this team envisioned a workforce of the future where everyone can say: • I add value and impact science. • We work anywhere, anytime and with anyone. • We broke down barriers and built up trust. • NSF bridged the gap between skills and needs. • My work has meaning and purpose, and we're inspired to reach our full potential. • High performance is not only expected, but continually achieved.	Goals 7 and 8 in the FY 2020 Annual Performance Plan in this Chapter measure activities that arose from and/or support the direction suggested by this SR: • To ensure that employee job requirements are aligned with competencies and skills needed for the future, starting in FY 2019, NSF is beginning to review and modernize existing position descriptions. • To foster a culture of inclusion through change management efforts, starting in FY 2019, NSF is encouraging the participation of all agency leaders in culture change activities.

Strategic Objective and Ranking	Summary of Strategic Review Findings	Progress Update as of Spring 2019

Objective 3.2 Processes and Operations
 	
Continually improve agency operations.
 	
Not Ranked
	Focus area: Renewing NSF: Making IT work for all (IT). This SR team proposed that NSF could lead the federal government in deploying smart IT solutions that help employees reach their full potential. Key elements of the vision for IT are that:
	
	• IT should be an intuitive extension of people;
	• IT governance should be inclusive and transparent;
	• NSF should be an early adopter of emerging technologies; and
	• NSF should be a leader in leveraging the data revolution.
		This Budget Request contains multiple references to activities that arose from, measure, and/or support the direction suggested by this SR, including:
		• Organizational Excellence Chapter
		  ◦ AOAM, Information Technology investment
		  ◦ Program Accounts, Proposal Management Efficiencies investment
		• Performance Chapter, FY 2020 Annual Performance Plan Goal 9: Streamline and simplify user interactions with IT systems and functions that support the merit review process.

FY 2018 ANNUAL PERFORMANCE REPORT AND FY 2020 ANNUAL PERFORMANCE PLAN

This document combines NSF's FY 2018 Annual Performance Report (APR) and FY 2020 Annual Performance Plan. FY 2019's goals and five years of historical information on individual goals are also provided when available. In FY 2018, NSF tracked progress toward its three strategic goals using seven performance goals, one of which is an Agency Priority Goal. Five of the seven goals fully achieved their targets in FY 2018 and two did not achieve one or more targets. Below is a tabular overview.

Goal ID	Performance Goals	FY 2018 Result	FY 2019 status	FY 2020 status
1	Agency Priority Goal: Expand Public and Private Partnerships	Achieved	Final year of goal	-
2	Ensure that Key Program Investments are on Track	Achieved	Continuing	Continuing
3	Ensure that Infrastructure Investments are on Track	Achieved	Continuing	Continuing
4	Use Evidence to Guide Management Decisions	Achieved	-	-
5	Make Timely Proposal Decisions	Not Achieved	Continuing	Continuing
6	Improve Review Quality	Partially Achieved	Continuing	Continuing
7	Foster a Culture of Inclusion	Achieved	Continuing	Continuing
8	Align Job Requirements with Competencies	-	First year of goal	Second year of goal
9	Improve User Interactions with IT Systems	-	First year of goal	Second year of goal

This section presents results for each performance goal in its strategic context, with reference to strategic goals, objectives, and targets from NSF's 2018-2022 Strategic Plan. Multiple years of trend data are available for NSF's longstanding quantitative performance measures (Infrastructure Investments and Timely Proposal Decisions). Other performance goals monitor progress towards multiyear goals, such as implementation of a new process (Improve Review Quality, Culture of Inclusion), upgrades to ongoing processes (Align Job Requirements, Improve User Interactions), or strategically important investments (Key Program Investments, Expand Public and Private Partnerships).

<u>Goal 1, Agency Priority Goal: Expand Public and Private Partnerships</u>
Lead Organizations: Directorate for Biological Sciences, Directorate for Computer and Information Science and Engineering.

Goal Statement
Expand public and private partnerships to enhance the impact of NSF's investments and contribute to American economic competitiveness and security.

Measure, Milestone, or Deliverable

Current Year		
FY	**Target**	
2019	By September 30, 2019, NSF's number of partnerships and award actions with other federal agencies, private industry, and foundations/philanthropies will grow by 5 percent, relative to the FY 2017 baseline, to make available infrastructure, expertise, and financial resources to the US scientific and engineering research and education enterprise.	
Reporting Year		
FY	**Target**	**Result**
2018	None	2017 = 56 partnerships (baseline) 2018 = to be reported in June 2019 on performance.gov
Previous Years		
This is a new goal in FY 2018. The topic was identified as a priority from the agency reform/Renewing NSF process.		

Strategic Alignment
Strategic Goal 2: Advance the capability of the Nation to meet current and future challenges. Objective 2.1, Societal Impacts: Support research and promote partnerships to accelerate innovation and to provide new capabilities to meet pressing societal needs.

About this Goal
Private industry, foundations, and non-profits, together with other federal agencies and international funding organizations, bring additional expertise, resources, and capacity to NSF-funded research. This, in turn, accelerates discovery and translation of research to products and services, and enhances preparation of the future workforce to benefit society and grow the American economy.

Partnerships require significant time and intellectual capital, as well as strategic foresight, in their development. NSF will improve efficiencies in developing, implementing, and managing partnerships to ultimately grow the number and scope of partnerships and maximize the scientific, economic, and societal impacts of its investments.

Discussion of FY 2018 Results
To collect reliable information on the number and types of partnerships and/or award actions in use at NSF, an NSF-wide Implementation Team determined data sources and designed a data collection methodology and inventory instrument that would be uniform across all units in FYs 2017 (baseline year), 2018, and 2019. For the purposes of this APG, a partnership activity was defined as a formal agreement between NSF and at least one external, domestic stakeholder and for which there was investment, other quantifiable

contribution, or new commitment formalized in the fiscal year. "Formal agreements" include, but are not limited to, Interagency Agreements (IAA) and Memoranda of Understanding (MOU). A partner was defined as the external stakeholder with whom NSF engages in a partnership activity. Partnership activities were categorized as interagency, private (including industry), and/or nonprofit/foundation, depending on the nature of the partners. Within NSF's 56 partnerships in FY 2017, 46 were with other agencies, seven were with the private sector, and three were with the nonprofit sector. Seven of the interagency partnerships also included one or more international partners.

FY 2019 and beyond

Reporting on this subset of NSF's partnerships will conclude at the end of FY 2019, although NSF expects to continue quantifying partnerships as appropriate. The working group is developing internal administrative tools, best practices, and processes to help NSF staff consider and evaluate the potential value of entering into new partnerships in the future. Use of these newly developed strategic resources will begin in FY 2019.

Goal 2, Ensure that Key Program Investments are on Track

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

Current and Upcoming Years

FY	Target
2020	1. Monitor the progress of selected NSF-wide investments using a common set of milestones and indicators: 10 Big Ideas. 2. Review the results with senior leaders quarterly in data-driven performance reviews.
2019	1. Monitor the progress of the following NSF-wide investments using a common set of milestones and indicators: 10 Big Ideas. 2. Review the results with senior leaders quarterly in data-driven performance reviews.

Reporting Year

FY	Target	Result
2018	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.	Achieved

Previous Years

FY	Target	Result
2017	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.	Achieved
2016	Monitor the progress of the following NSF-wide investments using a common set of milestones and indicators: NSF INCLUDES, INFEWS, and UtB.	Achieved
2015	Monitor the progress of Cognitive Science and 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

Strategic Alignment

- Strategic Goal 1: Expand knowledge in science, engineering, and learning, all Objectives
- Strategic Goal 2: Advance the capability of the Nation to meet current and future challenges, all Objectives.

About This Goal

NSF instituted the Key Program Investments goal in FY 2014 to track the interim progress of major investments towards their long-term goals. Each year, NSF highlights a number of cross-agency investments in its Budget Request to Congress. Most are described in the NSF-Wide Investments chapter of the Request. Although the overall impact of these investments might not be measurable for many years, tracking near-term indicators of progress can help the agency make formative changes or course corrections.

NSF selects a subset of these investments for closer quarterly tracking by leadership, based on internal assessments of the value that tracking is likely to add. For example, new programs, programs with recent changes, or high-profile programs may particularly benefit from the attention of leadership, and programs that are stably operating or sunsetting have reduced need for monitoring.

Discussion of FY 2018 Results

In FY 2018, NSF successfully monitored the progress of four NSF-wide investments—Understanding the Brain (UtB), Innovations at the Nexus of Food, Energy and Water Systems (INFEWS), Risk and Resilience, and NSF INCLUDES–using a common set of indicators and reviewed the results with senior leaders. The indicators that NSF chose to measure were programmatic inputs and outputs that can provide valuable signals to managers and leaders about a program's health, such as whether the program is being administered as planned or whether the program is generating enough interest from the community. The following were tracked quarterly in FY 2018:

- Input indicator: progress towards the investment's funding level target.
- Output indicators: solicitations issued, proposals received, awards made.
- Investment-specific activities: defined by each investment in its roadmap, this can include PI meetings, Ideas Labs, workshops, and evaluation contract deliverables.

These measures enabled managers and leaders to quickly gauge the status of a program's implementation, interest from the scientific community, whether the review process resulted in awards in a timely manner, and whether the program has met its internal goals for short-term outcomes. Tracking these measures over time provided managers and leaders with the opportunity to assess whether mid-course corrections were needed to improve program management and/or the overall direction of the investment.

FY 2019 and Planned FY 2020 Changes

NSF plans a shift for this goal in FY 2019 to focus on monitoring the implementation of the 10 Big Ideas, which are bold inquiries into the frontiers of science and engineering. By investing in these efforts, NSF endeavors to break down the silos of conventional scientific research to embrace the cross-disciplinary and dynamic nature of the science of the future. Six of the Big Ideas are research ideas, which build on the foundation built by NSF in fundamental research over the last fifty-seven years. The Research Big Ideas are complemented by four process-related Enabling Big Ideas, which are areas in which research endeavors to improve the way in which science is done, from impacting the workforce to developing the infrastructure that will drive the discoveries and aid the discoverers of tomorrow's science. More information about the individual Big Ideas can be found in this Request's Overview or in the NSF-Wide Investments chapter.

All Big Idea programs issuing solicitations in FY 2019 will be monitored as a KPI in FY 2019. This focus is expected to continue into 2020, although the final decision will be made in the first quarter of that year.

Goal Change History

By design, this goal's monitored programs change annually to match the funding priorities of the year. In addition to the annual change in the list of monitored programs, described in the narrative and the table below, the Goal Statements have changed slightly each year for this goal, as follows:

FY 2019: Ensure that key FY 2019 NSF-wide program investments are implemented and on track.
FY 2016: Ensure that key FY 2019 NSF-wide program investments are implemented and on track.
FY 2017: Ensure that key FY 2019 NSF-wide program investments are implemented and on track.
FY 2016: Ensure that key FY 2019 NSF-wide program investments are implemented and on track.
FY 2015: Meet critical targets for key program investments.
FY 2014: Meet critical targets for key FY 2014 program investments.

FY	CEMMS	SaTC	CIF21	SEES	UtB	INFEWS	NSF INCLUDES	Risk and Resilience
2014	✓	✓	✓	✓				
2015	✓	✓	✓	✓	✓			
2016					✓	✓	✓	
2017			sunset	sunset	✓	✓	✓	✓
2018	Sunset				✓	✓	✓	✓

CEMMS: Cyber-enabled Materials, Manufacturing, and Smart Systems
SaTC: Secure and Trustworthy Cyberspace
CIF21: Cyberinfrastructure Framework for 21st Century Science and Engineering
SEES: Science, Engineering, and Education for Sustainability
UtB: Understanding the Brain
INFEWS: Innovations at the Nexus of Food, Energy and Water Systems
NSF INCLUDES: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science

<u>Goal 3, Ensure that 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.

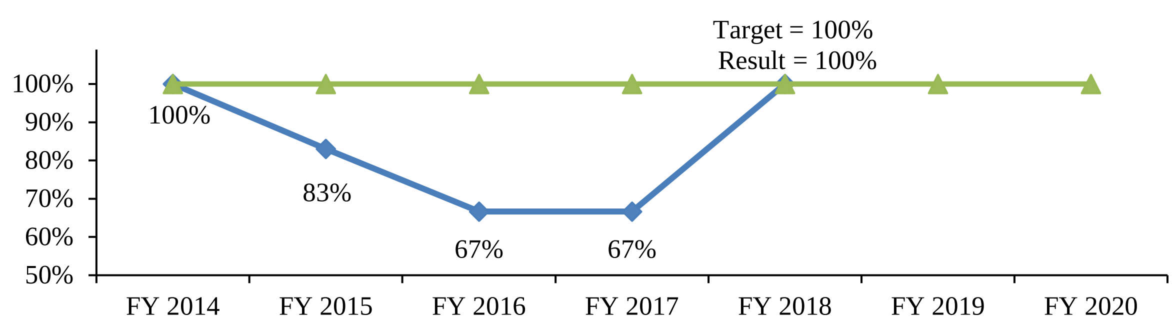
Measure, Milestone, or Deliverable

Current and Upcoming Years	
FY	**Target**
2020	Construction Project Monitoring (MREFC and R&RA): For 100 percent of • Major Facilities in the Construction Stage that are over 10 percent complete, and • Mid-scale Research Infrastructure in the Construction Stage with a Total Project Cost (TPC) above $20.0 million that are over 10 percent complete and using Earned Value Management (EVM), keep negative cost and schedule variance at or below 10 percent.
2019	Construction Project Monitoring: For 100 percent of MREFC facilities under construction that are over 10 percent complete, keep negative cost and schedule variance at or below 10 percent.

Reporting Year		
FY	**Target**	**Result**
2018	Construction Project Monitoring: For all (100 percent) MREFC facilities under construction that are over 10 percent complete, keep negative cost and schedule variance at or below 10 percent.	Achieved.

Measure Information for All Years

Construction Project Monitoring Performance Trends, FY 2014-2018 and including targets for FY 2019-2020



Strategic Alignment
Strategic Goal 1: Expand knowledge in science, engineering, and learning. Objective 1.1, Knowledge: Advance knowledge through investments in ideas, people, and infrastructure.

About This Goal
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. 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.

Discussion of FY 2018 Results

For more information about all projects currently funded from the MREFC account, see the Major Research Equipment and Facilities Construction chapter of this submission.

All of the projects that were over 10 percent complete by the end of FY 2018 were on track. At the end of FY 2018, the National Ecological Observatory Network (NEON) was 95 percent complete, the Daniel K. Inouye Solar Telescope (DKIST) was 88 percent complete, and the Large Synoptic Survey Telescope (LSST) was 60 percent complete. Each project had cost and schedule variances well below the 10 percent thresholds.

FY 2019 and Planned FY 2020 Changes

The net population of projects monitored by this goal is not expected to change in FY 2019. The NEON project is expected to complete construction during the FY 2019 reporting period, and the Regional Class Research Vessel (RCRV) project, to meet anticipated ocean science requirements for U.S. coastal waters, is expected to cross the percent complete threshold during FY 2019.

In FY 2020, the population of projects will expand. The Antarctic Infrastructure Modernization for Science (AIMS) project is anticipated to be awarded in FY 2019. It is anticipated that AIMS would then cross the percent complete threshold during FY 2020. Additionally, projects funded by the NSF Big Idea Mid-scale Research Infrastructure will be included within the project population for this goal. More specifically, those Mid-scale Research Infrastructure projects with a Total Project Cost (TPC) above $20.0 million and using Earned Value Management (EVM) will be reported.

Goal 4, Use Evidence to Guide Management Decisions
Lead Organization: Office of Information and Resource Management

Goal Statement
Use evidence-based reviews to guide management investments.

Measure, Milestone, or Deliverable

Current and Upcoming Years		
The HR and IT domains are the subjects of separate goals in 2019 and beyond.		
Reporting Year		
FY	**Target Summary (see "Goal Change History" for detailed target language)**	**Result**
2018	HRStat: NSF will develop metrics and targets to monitor the progress of three initiatives. PortfolioStat: NSF's IT governance boards will evaluate proposed investments and maintain a "green status" on the Federal IT Dashboard.	All targets achieved.
Previous Years (see "Goal Change History" for details)		
FY	**Target Summary**	**Result**
2017	HRStat: NSF will monitor progress of workforce initiatives and develop metrics for move to new NSF Headquarters. PortfolioStat: NSF's IT governance boards will evaluate proposed investments and maintain a "green status" on the Federal IT Dashboard.	3 of 4 targets achieved.
2016	HRStat: NSF will assess progress of workforce initiatives and focus evidence-based reviews on initiatives. PortfolioStat: NSF's IT governance boards will evaluate proposed investments and use cost and schedule data to inform investment decisions.	All targets achieved
2015	HRStat: NSF will establish indicators to assess workforce initiatives and focus evidence-based reviews on initiatives. PortfolioStat: NSF's IT governance boards will evaluate proposed investments and use cost and schedule data to inform investment decisions.	All targets achieved
2014	HRStat: NSF will develop a human capital management dashboard and establish quarterly reviews of HC metrics by senior management. PortfolioStat: NSF's IT governance boards will evaluate proposed investments and NSF will reduce IT costs.	All targets achieved

Strategic Alignment
Strategic Goal 3: Enhance NSF's performance of its mission, all Objectives.

About This Goal
HRStat and PortfolioStat are processes in which agency leaders conduct regular data-driven reviews of human resources and IT portfolio information.

HRStat
Since inception of this goal, the HRStat program and its targets have focused on providing NSF leadership with the human capital (HC) data and analyses needed to make decisions effecting targeted performance

objectives. In FY 2014, NSF developed a first-generation human capital management dashboard that included Federal Employee Viewpoint Survey scores and internal HR data. In FY 2015, the dashboard was updated to include three areas of focus for workforce initiatives that year: Employee Engagement, Recruitment and Retention, and Workload. In FY 2016, the dashboard and HRStat briefings were expanded to include data about Diversity and Inclusion. Federal regulations and OPM guidance governing HRStat changed in FY 2017 while NSF further expanded the scope of the HC and HR data it provided to leadership via HRStat briefings. Expanded HRStat briefings included progress updates toward agency HC goals established via NSF's Strategic Reviews, GPRA-MA, and OPM-required initiatives (e.g., OPM's Hiring Excellence campaign). In FY 2018, NSF's HRStat program shifted to satisfy specific requirements of the new 5 CFR 250 regulations and OPM guidance. In its current form, NSF's HRStat program provides updates and data relative to the agency's Human Capital Operating Plan that is aligned with, and a derivative of, the agency's strategic plan, annual performance plan, and agency reform plan (i.e., "Renewing NSF").

<u>PortfolioStat</u>
These targets monitor NSF's IT investment evaluation process. NSF's IT investments support the Foundation's business needs through a formal and disciplined IT investment review and decision-making process. Specifically, NSF's process for approving centrally-funded IT investments requires advocates for new IT investments to complete detailed justification and business case documentation. This ensures that advocates for new IT investments have fully considered the business need, benefits, impacts, and strategic alignment of each potential investment. This also helps the CIO and governance boards verify that IT, rather than policy changes or business process reengineering, is the appropriate solution to a business need. The process provides NSF's CIO and governance boards the information needed to review, approve, and prioritize investment proposals using a comprehensive evaluation methodology. Targets relating to monitoring of in-process investments cost and schedule data ensure that governance boards are aware of the progress and accomplishments for those investments that they recommended for funding.

Discussion of FY 2018 Results
<u>HRStat</u>
NSF's performance target for HRStat in FY 2018 ensured that the agency's HRStat program contained metrics and targets for agency initiatives related to NSF's new strategic plan, new OPM and/or Administration initiatives, and NSF's agency reform plan.

<u>PortfolioStat</u>
In preparation for the FY 2020 budget development, IT Governance groups carried out investment oversight activities to monitor the performance of all ongoing investments. Following established processes, the IT Governance groups evaluated the FY 2020 planned priorities for all ongoing and new proposed investments, ensuring alignment to agency strategic priorities.

FY 2019 and Planned FY 2020 Changes
To align with agency reform/Renewing NSF efforts, this goal was modified in FY 2019 and beyond (see Goals 8 and 9). HRStat and PortfolioStat continue within the CHCO and CIO reporting frameworks.

Goal Change History
<u>FY 2014 HRStat</u>
1. Develop a human capital management dashboard to report progress toward human capital (HC) goals and to monitor HC metrics, for use as an internal resource for informing investment decisions.
2. Establish a review process which culminates in quarterly reviews of HC metrics by senior management and which incorporates, to the extent possible, OPM's human capital accountability system requirements.

<u>FY 2014 PortfolioStat</u>
3. NSF's IT governance boards will evaluate and prioritize proposed investments for FY 2016.

4. NSF will move toward a standardized computing environment, reducing purchase costs by $300,000 below FY 2012 levels by FY 2014.
5. Migration to cloud email provider will reduce costs by approximately $240,000 below FY 2012 levels by FY 2014.

<u>FY 2015 HRStat</u>
1. Establish indicators to assess the impact and progress of three workforce initiatives designed to advance progress toward or address barriers to the accomplishment of mission related goals and objectives.
2. During FY 2015, focus at least two evidence-based reviews on the three identified workforce initiatives.

<u>FY 2015 PortfolioStat</u>

3. NSF's information technology governance boards will evaluate and prioritize proposed investments for FY 2017.
4. NSF's information technology governance boards will use cost and schedule data on existing investments to inform investment decisions for FY 2017. Percentage of IT projects within ten percent of budgeted costs and percentage of IT projects within ten percent of budgeted schedule will be tracked.

<u>FY 2016 HRStat</u>
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.

<u>FY 2016 PortfolioStat</u>

3. NSF’s information technology governance boards will evaluate and prioritize proposed investments for FY 2018.
4. NSF’s information technology governance boards will use cost and schedule data for ongoing investments to inform investment decisions for FY 2018.

<u>FY 2017 HRStat</u>
1. Monitor the progress of three workforce initiatives of strategic importance designed to meet the objectives of the Opportunities for Action in NSF’s FY 2014 and FY 2015 Strategic Reviews for Strategic Goal 3, Objective 1.
2. Develop metrics to demonstrate whether NSF met its workforce goals for transition to the new NSF Headquarters.

<u>FY 2017 PortfolioStat</u>

3. NSF’s information technology governance boards will evaluate and prioritize proposed investments for FY 2019.
4. 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.

<u>FY 2018 HRStat</u>
1. 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.

<u>FY 2018 PortfolioStat</u>
1. NSF’s IT 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.

<u>Goal 5, Make Timely Proposal 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

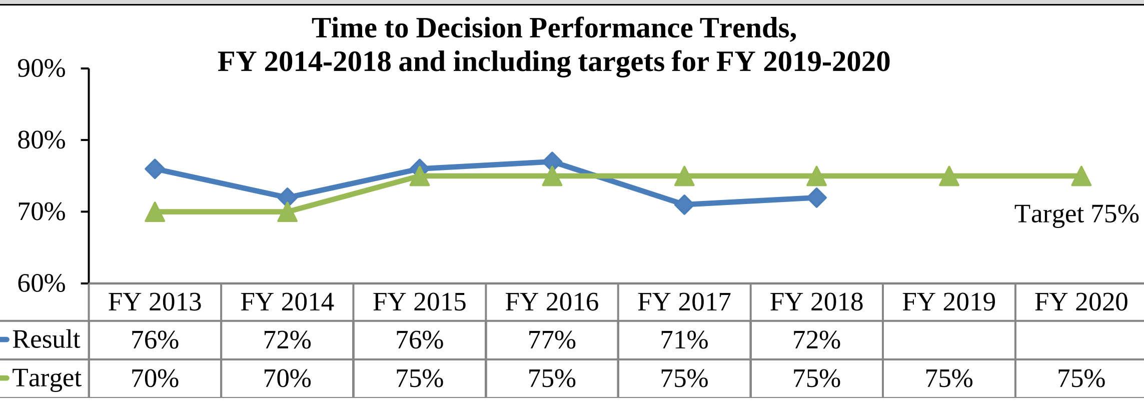
Current and Upcoming Years

FY	Target
2020	75 percent.
2019	

Reporting Year

FY	Target	Result
2018	75 percent.	Not Achieved. Result = 72 percent.

Measure Information for All Years (see “Goal Change History” for details)



	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Result	76%	72%	76%	77%	71%	72%		
Target	70%	70%	75%	75%	75%	75%	75%	75%

Strategic Alignment
Strategic Goal 3, Enhance NSF’s performance of its mission. Objective 3.2, Processes and Operations: Continually improve agency operations.

About This Goal
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. At the time of this goal’s establishment in the early 2000s, one of the most significant issues raised in customer satisfaction surveys was the time it takes NSF to process proposals, with dwell times only around 50 percent. Too long a time period inhibits the progress of research as it delays the funding process, but too short a time period may inhibit the merit review process. The 70 percent target sought to strike a balance between the need of the investigator for timely action and the need of NSF for a credible and efficient merit review system. NSF’s response time has been consistently above 70 percent for nearly two decades, and more recent surveys have shown that

this is now the second most common concern mentioned by PIs (see Goal 6, Improve Review Quality, for more recent survey results).

Discussion of FY 2018 Result

Explanation of Unmet Goal

NSF missed this goal in FY 2017 and FY 2018 for reasons related to the headquarters move at the end of FY 2017. NSF staff were directed to prioritize processing award decisions ahead of decline decisions in FY 2017 to facilitate an early close-out in advance of NSF's move to new headquarters in Alexandria. To reduce impact on individual employee performance, this goal was not included in any employee performance plans for the GWF performance period April 2017-March 2018. The FY 2017 result likely reflects this delay in decline processing and the FY 2018 result likely reflects this change in employee performance plans.

FY 2019 and Planned FY 2020 Changes

The 75 percent dwell time will continue.

Goal Change History

In FY 2015, this target was raised from 70 to 75 percent to be more in line with the historical trend of achievement between 75 and 80 percent. (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.)

<u>Goal 6, Improve Review Quality</u>
Lead Organization: Office of Integrative Activities, Office of the Director.

Goal Statement
Improve the quality of written reviews of NSF proposals.

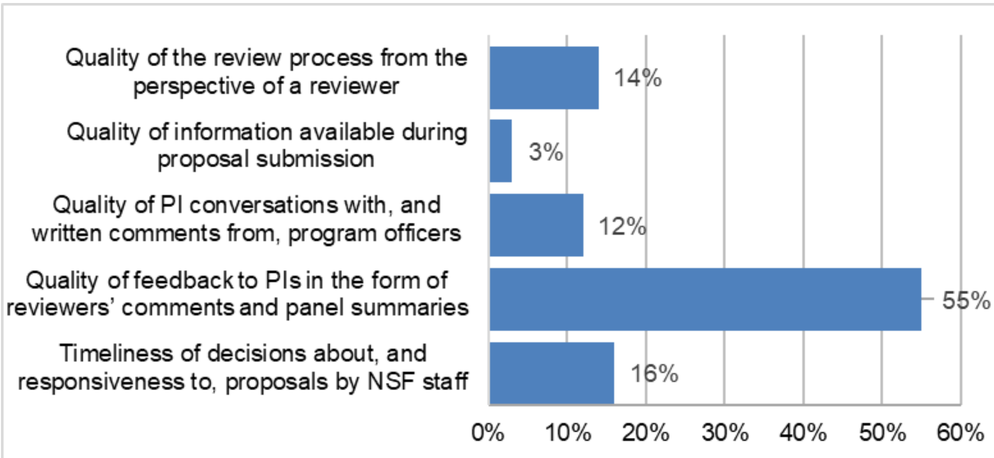
Measure, Milestone, or Deliverable

Current and Upcoming Years		
FY	**Target**	
2020	By September 30, 2020, 1. 140 NSF programs will have had reviewers view the presentation "Tips on how to write better reviews." 2. 10,000 reviewers of NSF proposals will have viewed "Tips on how to write better reviews" prior to preparing written reviews.	
2019	By September 30, 2019, 1. 60 NSF programs will have had reviewers view the presentation "Tips on how to write better reviews." 2. 8,000 reviewers of NSF proposals will have viewed "Tips on how to write better reviews" prior to preparing written reviews. 3. Improve the perceptions reported by survey respondents in a repeat survey of proposers and reviewers. • Increase the percentage of PI survey respondents who agree that written reviews are thorough from a baseline of 55 percent (2015) to 57 percent in FY 2019. • Increase the percentage of PI survey respondents who agree that written reviews are technically sound from a baseline of 63 percent (2015) to 65 percent in FY 2019.	
Reporting Year		
FY	**Target**	**Result**
2018	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.	1. Achieved 2. Not achieved.
Previous Years		
New goal in FY 2018.		

Strategic Alignment
- Strategic Goal 1: Expand knowledge in science, engineering, and learning, all Objectives
- Strategic Goal 3, Enhance NSF's performance of its mission. Objective 3.2, Processes and Operations: Continually improve agency operations.

About This Goal
This goal addresses and incorporates feedback NSF has received about its customer service. Committees of Visitors (COVs), program officers, and principal investigators frequently note that the quality of individual written reviews is variable. In 2015, NSF conducted a survey of researchers who were submitting

and/or reviewing proposals. Survey respondents identified the quality of reviews as the factor that would have the most significant effect on improving their proposals and fostering science (see chart below, n=22,174 respondents). A strategic review in the spring of 2015 recommended that NSF apply what was learned from the PI and reviewer survey to inform a new performance goal aimed at improving customer service. This goal was designed in response to that recommendation.



This goal measures the implementation of a pilot program, initiated in December 2016, to improve the quality of written reviews of NSF proposals. The pilot encourages NSF programs to use the video presentation "Tips on how to write better reviews" early in the review process to orient reviewers and provide information on how to write more effective reviews. The assumption is that orienting reviewers before the reviews are written (as opposed to at the beginning of a review panel, at which time the reviews have been drafted but not finalized) helps reviewers better understand and apply the review criteria. The intention is to make written reviews more useful to both principal investigators and NSF program staff.

Discussion of FY 2018 Results

Through September 30, 2018, reviewers across 127 programs viewed the orientation video, exceeding the target of 50 programs. 3,022 reviewers viewed the orientation video prior to preparing written reviews, not reaching the target of 5,000 reviewers.

<u>Explanation of Unmet Goal</u>

Goals in their first year often take time to ramp up to full performance. After a midyear progress review, outreach within NSF and to the community was increased, which led to increased performance the second half of the fiscal year, resulting in exceeding the target for the number of programs. Of the two targets, the reviewer target was anticipated to be harder to achieve. Increasing the number of programs can be done solely with outreach to NSF employees, but increasing the number of reviewers viewing the video involves influencing the behavior of thousands of external reviewers. Nevertheless, the outreach effort did lead to a sharp rise in the second half of the year in the number of reviewers who saw the video.

FY 2019 and Planned FY 2020 Changes

NSF will conduct another survey in FY 2019 to learn whether the perceived quality of reviews has changed. Despite the funding lapse in Q2 of FY 2019, this survey is still scheduled for FY 2019. In light of the exceeded FY 2018 target, the target for number of programs was increased for FY 2020 to 140.

Goal 7, Foster a Culture of Inclusion

Lead Organization: Office of Diversity and Inclusion, Office of the Director.

Goal Statement

Foster a culture of inclusion through change management efforts resulting in change leadership and accountability.

Measure, Milestone, or Deliverable

Current and Upcoming Years		
FY	**Target**	
2020	In FY 2019 and FY 2020, all NSF leaders will participate in culture change activities.	
2019		
Reporting Year		
FY	**Target**	**Result**
2018	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.	1. Achieved. Four units. 2. Achieved. Increases averaged 10 percent.
Previous Years (see "Goal Change History" for details)		
FY	**Target Summary**	**Result**
2017	1. By September 30, 2017, ODI will conduct the new IQ process with three additional organizational units. 2. Improve the three NSF organizational units' New IQ Self-Survey Scores by seven percent above established baseline.	No targets achieved.
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
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

Strategic Alignment

Strategic Goal 3, Enhance NSF's performance of its mission. Objective 3.1, Human Capital: Attract, retain, and empower a talented and diverse workforce.

About This Goal

This goal incorporates principles from Renewing NSF, the agency operational reform plan initiated in FY 2017 in response to M-17-22.

Fostering inclusive work environments and realizing the full potential of the workforce's diversity requires agencies to employ effective management practices. NSF puts a high premium on diversity and inclusion: by engaging the talent of all our workforce, individuals are empowered to realize their full potential; by insuring that our workforce is diverse, our collective ability to deliver on our scientific mission is enhanced. NSF is always looking for ways to intensify and innovate diversity efforts through active leadership and include and engage everyone in the workplace. This goal will encourage leaders to participate in engagement initiatives being used around the Foundation, including, but not limited to:

- New Inclusion Quotient (New IQ) workshops,
- Diversity and Inclusion Dialogues,
- Workforce Inclusiveness Assessment,
- Special Emphasis observances,
- Employee Resource Groups,
- unconscious bias awareness training, and
- inclusion learning activities for all employees.

Discussion of FY 2018 Results

Unit	2016 NewIQ score (from FEVS)	2018 post-test	Increase
Unit 1	57%	70%	+13%
Unit 2	57%	67%	+10%
Unit 3	77%	85%	+8%
Unit 4	70%	80%	+10%

Starting in FY 2016, this goal focused on bringing the New IQ process to NSF to increase the inclusion scores of specific organizational units. The Office of Personnel Management (OPM), in partnership with the Department of Veterans Affairs, developed the (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.

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. The most recent FEVS scores, or a self-survey conducted at the beginning of the ninety-day process, establish a baseline for the group, and the survey is distributed again at the end of the process. The expected outcome of the process is improved employee engagement levels, as measured by an increase in the overall New IQ scores and corresponding FEVS scores over time.

In FY 2018, NSF used the New IQ process to improve scores across four organizational units by an average of 10 percent.

FY 2019 and Planned FY 2020 Changes

In FY 2019, and beyond, this goal will expand beyond the New IQ to also count other inclusion activities.

Goal Change History

NSF has had a performance goal relating to diversity and inclusion since FY 2011. For five years, goals were largely focused on NSF's efforts to attain "Model EEO Agency" status. Inclusion represented a new direction for this goal since FY 2016. The focus on leadership represents a new direction for this goal in FYs 2019 and 2020. For more information, refer to the FY 2015 Annual Performance Report in the FY 2017 NSF Budget Request.[1]

[1] nsf.gov/about/budget/fy2017/pdf/56_fy2017.pdf

Goal 8, Align Job Requirements with Competencies

Lead Organization: Division of Human Resource Management, Office of Information and Resource Management

Goal Statement

Ensure that employee job requirements are aligned with competencies and skills needed for the future.

Measure, Milestone, or Deliverable

Current and Upcoming Years	
FY	**Target**
2020 2019	In FY 2019 and in FY 2020, the Division of Human Resource Management will review, modernize, or eliminate 10 percent of the existing position descriptions requiring review.
Reporting Year	
2018	*See Goal 4, "Use Evidence to Guide Management Decisions," for precedents.*

Strategic Alignment

Strategic Goal 3, Enhance NSF's performance of its mission. Objective 3.1, Human Capital: Attract, retain, and empower a talented and diverse workforce.

About This Goal

This goal incorporates principles from Renewing NSF, the agency operational reform plan initiated in FY 2017 in response to M-17-22.

Technological improvements have automated many tasks once performed by NSF staff. Requirements for NSF's administrative staff have evolved from the more traditional competencies related to general clerical and office tasks such as categorizing, processing, and tracking paper forms to more advanced competencies related to the use of multiple automated data systems. Additionally, the increasing high number of proposals NSF receives, processed by the relatively stable number of program officers, means greater support is needed in data processing, data mining, analytics, and use of automated processes. NSF is also putting into place efforts to enable transdisciplinary, convergent research, and the agency needs to ensure its current and future workforce can adapt to this convergent approach. NSF will review and realign its workforce to ensure its greatest resource–its people–are equipped with the knowledge, skills, and abilities for success now and in the future. Ultimately, this will result in increased alignment between NSF's organizational structure, its core mission, and strategic plan.

NSF will improve performance and increase accountability by systematically reviewing the NSF workforce from top to bottom. This review will allow NSF to revise position descriptions (PDs) that are outdated or do not reflect current and future work responsibilities. This PD modernization effort will enable NSF to identify the skills needed in today's work environment and will establish more relevant opportunities for training and developing NSF's existing workforce, while also enabling hiring managers to better target recruitment and outreach efforts to obtain the highest caliber of external candidates.

FY 2019 and Planned FY 2020 Changes

This is a new goal in FY 2019.

<u>Goal 9, Improve User Interactions with IT Systems</u>
Lead Organization: Office of the Chief Information Officer and the Division of Information Systems, Office of Information and Resource Management

Goal Statement
Streamline and simplify user interactions with IT systems and functions that support the merit review process, reducing non-value-added steps and reducing the time spent managing the proposal and award lifecycle.

Measure, Milestone, or Deliverable

Current and Upcoming Years	
FY	**Target**
2020	By the end of FY 2020, 1. NSF IT systems will have been available 99.6 percent of the time, excluding 469 hours of planned downtime. 2. 86 percent of internal merit review functions will be accessible through a single portal. 3. 32 percent of external merit review functions will be accessible through a single portal.
2019	By the end of FY 2019, 1. NSF IT systems will have been available 99.5 percent of the time, excluding 469 hours of planned downtime. 2. 72 percent of internal merit review functions will be accessible through a single portal. 3. 32 percent of external merit review functions will be accessible through a single portal.
Reporting Year	
2018	*See Goal 4, "Use Evidence to Guide Management Decisions," for precedents.*

Strategic Alignment
Strategic Goal 3, Enhance NSF's performance of its mission. Objective 3.2, Processes and Operations: Continually improve agency operations.

About This Goal
This goal incorporates principles from Renewing NSF, the agency operational reform plan initiated in FY 2017 in response to M-17-22.

As NSF positions itself to operate as a more agile organization, information technology will play a major role in enabling NSF's mission and allowing NSF to remain flexible to adapt to reform areas. NSF will look to leverage state-of-the-art IT solutions to develop flexible tools that support the formation of agile work teams; to drive changes in the way research is solicited, identified, and funded; and to ensure user adoption is achieved to the maximum extent possible while also easing the use of IT systems. This emphasis on efficiency and improved service to end users will ensure that IT responds rapidly to changes in the way NSF is organized and carries out its mission, with the goal of ensuring that NSF IT tools minimize staff workload and simplify decision-making by providing accurate data, easy-to-use interfaces, and readily available and reliable access.

Indicator 1, Percent of Systems Availability, measures the amount of time that the system is up and running, and is available for access because connectivity is available (i.e. no network or internet outages impact accessibility). Indicator 2 is the percentage of internal merit review functions accessible through a single portal. Indicator 3 is the percentage of external merit review functions accessible through a single portal.

FY 2019 and Planned FY 2020 Changes
This is a new goal in FY 2019.

FY 2018 MANAGEMENT CHALLENGE PROGRESS REPORT

Background

Under the Reports Consolidation Act of 2000, NSF's Inspector General is required to summarize what it considers to be the most significant management and performance challenges facing NSF in the coming year in a memo to the NSF Director. The management challenges are identified by NSF's Inspector General and announced at the beginning of each fiscal year. In response, the Director issues a memo to acknowledge receipt of the OIG Management Challenges and to provide a report on NSF's progress and achievements made over the prior year.

The OIG's challenges, NSF's response, and NSF's progress update towards addressing previously identified challenges are included in the annual Agency Financial Report (AFR) published in November on NSF's website.[1] This section provides NSF's progress report highlighting the significant actions taken in FY 2018 on the management challenges identified by NSF's Inspector General at the beginning of that fiscal year.

Enterprise Risk Management

Starting in FY 2018, NSF's Progress Report applied its Enterprise Risk Management framework to document its assessments of the inherent and residual risks for each of the OIG's Challenges for FY 2018, including actions to mitigate risks. NSF management's overview of the challenges presented represent NSF's view of the residual risk in light of the key actions NSF has already taken to address the OIG-identified challenge. Further, NSF management developed the anticipated milestones in consideration of NSF's strategic objectives, the risks inherent to NSF's work, and the key actions NSF has already taken to address those risks.

In response to NSF's incorporation of ERM principles in its FY 2018 report, the OIG updated its reporting format for FY 2019, and recognized NSF's progress by removing two Management Challenges cited for FY 2018: Management of the Government's Records and Cybersecurity and Information Technology Management. These changes in NSF's and OIG's reports enable constructive dialogue between NSF and the OIG about risk, and advance fulsome consideration by NSF of the OIG's new challenges.

<u>FY 2018 Management Challenges</u>

- Major Multi-User Research Facilities Management
- Business Operations Management: Improper Payments
- Business Operations Management: DATA Act
- Business Operations Management: Managing the Government's Records
- Business Operations Management: Subrecipient Monitoring
- Management of the *Intergovernmental Personnel Act* (IPA) Program
- U.S. Antarctic Program (USAP) Management
- Cybersecurity and Information Technology (IT) Management
- Encouraging the Ethical Conduct of Research

<u>FY 2019 Management Challenges</u>

- Managing major multi-user research facilities
- Meeting Digital Accountability and Transparency Act of 2014 (DATA Act) reporting requirements
- Eliminating improper payments
- Managing the Intergovernmental Personnel Act (IPA) Program
- Managing the U.S. Antarctic Program
- Encouraging the ethical conduct of research

[1] www.nsf.gov/about/performance

Major Multi-User Research Facilities Management
Co-Leads: Chief Financial Officer and Chief Officer for Research Facilities

<u>Summary of OIG Identified Challenge</u>
Ensure consistent implementation of its expanded controls for major facilities oversight.

<u>NSF's Key Actions to Address the Challenge</u>
Agency Actions Taken in Prior Fiscal Years

- Strengthened controls over NSF's major facility portfolio through the development of several new policies and procedures in FY 2016 and FY 2017 including: (1) retaining a portion of the recipients' contingency funds; (2) periodically conducting cost incurred audits; (3) completing a cost proposal review for reasonableness of proposed costs; (4) obtaining an independent cost review of the proposed budget; (5) conducting earned value management system verification, validation and acceptance; and (6) reviewing proposed fees and requiring recipients to track fee expenditures.
- Developed the Major Facilities A-123 Oversight Process Narrative and revised the *Large Facilities Manual* (LFM) to incorporate new guidance for recipients related to cost estimating and analysis.

Actions Taken in FY 2018

- Appointed a new Chief Officer for Research Facilities (CORF) in the Office of the Director to ensure agency-wide acceptance of policies and procedures related to oversight of major facilities.
- Appointed Accountable Directorate Representatives (ADR) in each Directorate with major facilities and formed the Major Facilities Working Group (consisting of the ADR's) to review and socialize policies and procedures related to the oversight of major facilities.
- Formed the Facilities Governance Board to approve major facility oversight policies and procedures at the agency level.
- Revised the Integrated Project Team (IPT) Standard Operating Guidance (SOG) to include facilities in the Operations Stage.
- Developed the Core Competency SOG to codify the minimum competencies for the core IPT members.
- Conducted an independent third-party review of NSF's strengthened policies and procedures related to cost surveillance.

<u>NSF Management's Overview of the Challenge</u>
NSF understands the importance of overseeing its recipients' management of major facility awards. The agency also recognizes the importance of assessing prospective recipients' capabilities for managing proposed awards. Over the past several years, NSF has been in the process of strengthening its policies and procedures as illustrated above. This includes an annual major facilities portfolio risk assessment to determine the necessary BFA-led reviews and audits to be conducted by the Large Facilities Office (LFO) and the Cooperative Support Branch (CSB). In close cooperation with program, LFO and CSB conduct the reviews described above, which were specifically created to safeguard NSF's investments in supporting the scientific endeavor. NSF leadership has shown its commitment to oversight in the past several years by strengthening the LFO and in establishing the new CORF position. The new governance structure now in place will help ensure consistent implementation of its expanded controls for major facilities oversight.

NSF has recently undergone a Government Accountability Office (GAO) review related to its No Cost Overrun Policy and oversight practices related to recipient cost and schedule development. In the June 2018 report entitled National Science Foundation: Revised Policies on Developing Costs and Schedules Could Improve Estimates for Large Facilities (GAO-18-370), the GAO recommended that NSF should revise its policies for estimating and reviewing the costs and schedules of large facilities projects to better incorporate the best practices in GAO's guides. NSF agreed with the GAO recommendations and has a corrective action plan in place to address the findings.

Based on NSF's risk-based evaluation of this Management Challenge, coupled with activities already completed and those planned for FY 2019, NSF has determined that the residual risk impact is "very low" and the likelihood is "low." NSF is confident that its current and planned policies and procedures related to major facility cost and schedule oversight adequately consider and balance risk, resources, and stewardship of federal funds.

<u>NSF's Anticipated Milestones</u>

- Anticipate receipt of independent third-party report related to cost surveillance – <u>Q1 FY2019.</u>
- Finalize Selection of Independent Cost Estimate Review SOG already implemented in practice – <u>Q1 FY2019.</u>
- Describe the purpose and customary methods for sensitivity analysis and application of GAO's 12 steps of a high-quality cost estimating process (LFM Section 4.2) – <u>Q3 FY 2019.</u>
- Finalize and align BFA SOGs related to selection of independent cost estimate reviews, standardized cost analysis, and pre-award budget reviews to specifically address American Innovation and Competitiveness Act requirements and GAO good practices – <u>Q4 FY 2018.</u>
- Develop and implement a new Major Facilities Review SOG to more fully utilize external review panels in addressing elements of cost and schedule – <u>Q2 FY 2019.</u>
- Create a new LFM Section 4.3, *Schedule Development, Estimating, and Analysis* – <u>Q3 FY 2019.</u>
- Update BFA Cooperative Support Branch's Standardized Cost Analysis Guidance SOG to include assessment of schedule due to the potential impact scheduling has on costs – <u>Q4 FY 2018.</u>

Business Operations Management: Improper Payments
Lead: Chief Financial Officer

Summary of OIG Identified Challenge
(a) Ensure proper payments to awardees for the $7 billion issued annually in grant and cooperative agreement payments without verification;
(b) address substantial concerns with the depth, substance, and documentation of the NSF risk assessment;
(c) address significant limitations in NSF's analysis of six of the nine OMB risk factors; and
(d) improve assessment of NSF payments to employees.

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years
- Developed and published SOG for improper payments risk reviews incorporating the nine Improper Payment Elimination and Recovery Act (IPERA) risk factors and additional considerations from the OIG review report.
- Completed improper payments risk reviews for FY 2016 and FY 2017. The risk reviews included input from subject matter experts (SMEs) for grants, contracts, charge cards, and payments to employees. Both reviews concluded that NSF did not have a significant risk of improper payments.
- OIG inspection of the FY 2016 and FY 2017 risk reviews found NSF in compliance with IPERA requirements.

Actions Taken in FY 2018
- Conducted advanced and baseline grant monitoring activities including grant payment testing.
- Operated, evaluated, and reported on an effective internal controls program providing assurance that NSF controls over grant and grant payment processes are properly designed and operating effectively.
- Collaborated with the OIG, BFA, and program offices on risk reduction activities including completion of an initial fraud risk assessment for grants under the Fraud Reduction and Data Analytics Act.
- Completed an improper payments risk assessment for FY 2018 that built on the improper payments risk reviews completed during FY 2016 and FY 2017.

NSF Management's Overview of the Challenge
NSF appreciated the OIG's current determination of NSF's compliance with IPERA and closure of all recommendations from the previous OIG reports. The reports clearly validate that NSF has taken the steps necessary to demonstrate compliance and effectiveness in the agency's implementation of IPERA because NSF has:
- Demonstrated strong commitment and top leadership support to incorporate risk management concepts into business processes and management functions;
- Ensured that NSF has the people and resources to effectively comply with IPERA by assigning a senior staff associate responsible for coordinating and integrating risk management and program integrity activities;
- Developed and completed a corrective action plan in July 2016 that addressed the root causes of the IPERA reporting issue, implemented solutions, and completed all OIG recommendations;
- Established processes to monitor and validate the effectiveness and sustainability of the corrective measures; and
- Incorporated corrective measures into policy and process documentation.

<u>NSF's Anticipated Milestones</u>

- Continue advanced and baseline grant monitoring activities including grant payment testing.
- Continue internal controls program activities to provide assurance that NSF controls for its payment processes are operating effectively.
- Continue collaboration with the OIG on risk reduction activities.
- Continue to improve improper payments risk assessment and reporting compliance activities.

Business Operations Management: DATA Act
Lead: Chief Financial Officer

Summary of OIG Identified Challenge
Address challenges set forth in OIG audit report 18-2-001, dated November 17, 2017, reporting on the OIG's assessment of completeness, timeliness, quality, and accuracy of data submitted by NSF in accordance with the DATA Act.

NSF's Key Actions to Address the Challenge
Actions Taken in FY 2018
Developed and implemented Corrective Action Plan in response to the FY 2017 audit with the following actions:

- Examined processes identified as potential audit risks, identified ways to improve or strengthen the processes, and documented changes in NSF's standard operating procedures.
- Submitted corrections for any data errors identified in the audit.
- Included comments with NSF's submissions to explain legitimate differences between File C (Award and Financial Detail) and Files D1/D2 (Financial Assistance and Procurement Award and Awardee Attributes).
- Reviewed submission process with the internal controls team and identified opportunities for improvement.
- Performed policy review of the application of "legitimate differences" guidance to warnings when linking Files C to D1/D2.
- Worked closely with the DATA Act Audit Collaboration Working Group of the CFO Council (CFOC) and the Council of the Inspectors General on Integrity and Efficiency (CIGIE) to identify issues to be addressed to improve DATA Act implementation and clarify government-wide guidance and audit standards.
- Worked with a subgroup of the Financial Assistance Committee for E-Government (FACE) in collaboration with a DATA Act Internal Control subgroup of the CFOC to provide a solid framework and data quality plan template that agencies can leverage and customize to develop their own data quality plans.
- Initiated implementation of OMB Circular A-123 Appendix A, requiring agencies to maintain a Data Quality Plan that considers the incremental risks to data quality in federal spending data and any controls that would manage such risks. NSF's data quality plan will leverage the existing plans for the Financial (Files A-C) and Procurement (File D1) data as well incorporate the new data quality requirements for the Financial Assistance (File D2) data.
- Reviewed SharePoint processes to ensure all required BFA Division Director validations are complete, properly labelled, and available for Senior Accountable Official (SAO) review.

NSF Management's Overview of the Challenge
The Digital Accountability and Transparency Act (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. On April 28, 2017, NSF successfully met the DATA Act's requirement for federal agencies to begin submitting data to Treasury. From the outset, NSF prioritized DATA Act implementation, initially naming an SAO from the Office of the Director and later transitioning that role to the NSF Chief Financial Officer where it remains. The agency allocated appropriate resources to both the implementation and operations phases of its DATA Act work, leveraging agency staff from BFA and OIRM as well as contract resources. Early on, NSF recognized the importance of government-

wide engagement and earned the Treasury Secretary's Certificate of Appreciation in recognition of NSF's outstanding commitment to collaboration on this government-wide implementation challenge.

The DATA Act required the OIG of each federal agency to review a sample of the financial data submitted by the agency and report on its completeness, timeliness, quality, and accuracy, as well as the implementation and use of consistent data standards by each agency. The NSF OIG issued its report on November 17, 2017. NSF generally agreed with the audit recommendations and has addressed them all, developing corrective actions that have been resolved and closed by the OIG. In connection with this work, NSF staff conducted a root cause analysis of its challenges, noting that many of the OIG-identified errors were government-wide in nature and beyond NSF's control, which the OIG recognized in its report.

Among the corrective actions NSF has implemented is the agency's continued leadership and engagement in government-wide DATA Act-related work. On June 6, 2018, OMB issued new guidance, Appendix A of OMB Circular A-123, superseding prior DATA Act guidance and creating a requirement for agencies to develop data quality plans that include management assurance in the quality of its data. NSF analysis confirmed that the prior guidance had dramatically amplified NSF error rates because auditors relied on it to evaluate errors at the transaction level, rather than at the data element level. Agencies will now be audited against the revised approach, and NSF is confident that the agency's reported error rate will drop significantly as a result.

NSF's progress on the DATA Act has been enabled by the NSF Deputy CFO's deep engagement in supporting the activities relating to the Audit Collaboration Working Group of the CFOC and CIGIE, which will develop agency best practices for implementing the new guidance. The CFOC is also collaborating with GAO and CIGIE as they develop their related audit guidance, which will take the new OMB guidance into account. In addition, the NSF Division Director for BFA's Division of Institution and Award Support and other NSF senior staff are supporting the government-wide financial assistance community's work to develop a framework for the required data quality plans, which NSF will leverage as it prepares its own required plan.

Based on NSF's risk-based evaluation of this Management Challenge, along with the causes analyzed and actions that NSF has taken to date, NSF believes that its risk of reporting inaccurate, incomplete, and untimely data has been significantly reduced.

<u>NSF's Anticipated Milestones</u>

- Participate in government-wide working groups to develop a DATA Act Playbook to support federal agencies' compliance and audit readiness;
- Develop an NSF DATA ACT data quality plan; and
- Monitor changes to NSF systems to determine impact on DATA Act reporting.

Business Operations Management: Managing the Government's Records
Lead: Office Head, OIRM

Summary of OIG Identified Challenge

(a)	(b)	(c)
Ensure compliance with the National Archives and Records Administration's (NARA) August 24, 2012, Managing Government Records Directive (M-12-18) to take specific actions to reform records management policies and practices by appointed dates.	Continue initiatives to reduce the amount of paper, supplies and equipment that NSF uses and stores given less office space available in the new NSF headquarters as well as efficiently and effectively manage the scanning/digitization effort to reduce the amount of paper.	Provide updated records management training to staff in accordance with NARA Bulletin 2017-01 (Agency Records Management Training Requirements).

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years

- Verified and validated the accuracy of the report on records that were 30-years old or more and determined there are no records meeting this criterion in existence within the agency. (October 2015)
- Conducted a review of records at the Federal Records Center (FRC) locations where agency records are stored and determined that no unscheduled records remain there. (October 2015)
- Began presenting an overview of general records management responsibilities at NSF's New Employee Orientation sessions. (August 2017)
- Revised NSF records management training course to cover all NARA-required elements. (June 2017)
- Scanned over 7,000 permanent and temporary records from August 2016 to August 2017 during the process of relocating to the new NSF headquarters as part of an agency-wide "green" initiative to eliminate paper and property. The initiative ultimately reduced 1,200,000 pounds of paper and property, compared to a goal of 500,000 pounds.

Actions Taken in FY 2018

(a)	(b)	(c)
• Issued NSF Bulletin 18-05, Records Management Program, and NSF Bulletin 18-04, Managing Records in Electronic Messages, to identify staff responsibilities at all levels of the agency. • Issued guidance for executing NSF's Capstone Officials' Email Management Program under Bulletin 18-03. • Issued NSF Bulletin 18-12, Managing Email of Supervisory, Support and/or Administrative Personnel as Records • Classified OIG and Office of the General Counsel's electronic records as official records. • Completed an analysis of records at the FRC. • Implemented blacklist capability on NSF-managed mobile devices to prohibit restricted application downloads.	• Implemented a full-text search capability in the Electronic Records Management System (ERMS). • Created an online training for the ERMS.	Issued NSF Bulletin 18-06, Required Records Management Training, to implement new requirement for all staff to take annual records management training. New personnel on boarding after April 30, 2018 are required to complete the course within 60 days of employment and annually each fiscal year thereafter. All other personnel are required to complete this course by September 30, 2018, and annually each fiscal year thereafter.

• Issued updated NSF Bulletin 18-07, Mobile Communications Devices, to include guidance related to electronic records on NSF-issued smartphones. • Updated mobile device rules of behavior to comply with NSF Bulletin 18-07. • Added instructions to the agency's standard operating procedures (SOP) for social media on how to capture and retain records in social media posts on NSF accounts.		

<u>NSF Management's Overview of the Challenge</u>

NSF is on track to comply with NARA's 2012 directive (M-12-18) to take specific actions by appointed dates to reform the policies and practices for the management of government records. The agency has committed appropriate resources to prioritize its compliance and has already met the requirements for Goal 2 in the 2012 directive. NSF's anticipated milestones focus on completing the requirements for Goal 1 and ensuring it maintains compliance with Goal 2. The Foundation has worked closely with senior management and the OIG to formulate corrective action plans that outlined many of the actions taken in FY 2018 and to be taken in the future. Actions taken to-date have significantly reduced the inherent risk, such as non-compliance and lost records, to a low level.

The NSF digitization project in preparation for the move to Alexandria was a great success. Multiple offices around the building not only reduced their paper footprint to fit into their new space, but now have excess storage capacity they are looking to repurpose. Among other benefits, NSF's above-described actions reduced the inherent risk associated with paper records, including space limitations and loss of records; therefore, the agency plans to continue to promote digitization of paper records.

NSF records management training content and policy complies with NARA Bulletin 2017-01. Formalized, required records management training will promote transparency and accountability in the management of federal records. NSF implementation of this training has addressed the inherent risk set forth in the OIG's management challenge, bringing the residual risk to a low level. Agency progress in this area is demonstrated by the results of the NARA on-site assessment conducted in May 2018 where NARA reviewed NSF's Records Management Training Program and policies related to records management. Senior staff within the NSF Division of Administrative Services Records Management Section were engaged with NARA and demonstrated the new *Records Management for Everyone and eRecords Management System* online training courses. NARA reviewed five recently issued records management-related NSF Bulletins. At the end of the assessment, NARA praised the training modules and bulletins, and said they would like to highlight NSF's records management program as a model for the federal government.

<u>NSF's Anticipated Milestones</u>

(a)	(b)	(c)
• Update remaining records schedules to classify electronic records as official agency records and get approval from the Archivist of the United States by the end of FY 2019. • Issue a policy on managing email of supervisory, support, and administrative personnel as records by December 2018.	• Destroy all records at the FRC that have met their disposition date by the end of FY 2018. • Complete an agency-wide records inventory by November 2018.	• Monitor compliance with annual records management training requirement for staff utilizing LearnNSF automatic tracking capability.

• Complete the NARA 2019 Annual Records Management Self-Assessment, the Annual Federal Email Management Report, and the Annual Senior Agency Official for Records Management Report by April 2019. • Implement a tool for automated capture of text messages on NSF-managed mobile devices by November 2018.	• Continue to scan records to put in ERMS.	• Initiate quarterly workshops for NSF-wide Division Records Custodians by December 2018.

Business Operations Management: Subrecipient Monitoring
Lead: Chief Financial Officer

Summary of OIG Identified Challenge
Transparency and oversight of NSF funds passed through to subrecipients (e.g. ensure awardees review sufficient cost information to demonstrate that subrecipients' costs are allowable, fair, and reasonable).

NSF's Key Actions to Address the Challenge
Actions Taken in FY 2018

- Piloted a Targeted Review Assessment (TRA) methodology to assess compliance with prime awardee oversight of subrecipients.
- Reviewed NSF's Advanced Monitoring Program subaward module assessment protocols based on TRA findings and *Uniform Guidance* requirements.
- Continued to require prime awardees to take corrective actions for findings related to subaward monitoring.
- Continued practice of applying 1 to 5 risk points to awards containing subawards at or exceeding $100,000 as part of NSF's annual risk assessment process.
- Updated the standard NSF budget form to eliminate awardee confusion around subcontracts vs. subawards. The form now only allows for subawards.
- Changed award notification language to reflect subaward vs. subcontract.
- Updated NSF's fact sheet on subrecipient monitoring to reference requirements in 2 CFR §200.331 for pre- and post-award monitoring.

NSF Management's Overview of the Challenge
Historically, NSF has understood the importance of overseeing its recipients' management of large and multiple subawards. The Foundation also recognizes the importance of assessing prospective awardees' capabilities for managing proposed subawards. NSF currently has in place a risk-based approach to oversee its award recipients' subaward management through advanced monitoring activities, including Advanced Monitoring Site Visits, Desk Reviews, and Business Systems Reviews (BSRs). NSF leadership has shown its commitment to oversight for nearly two decades by the establishment and continued support for the Division of Institution and Award Support (DIAS) and the Large Facilities Office (LFO) within NSF's Office of Budget, Finance, and Award Management. These offices were specifically created to safeguard NSF's investments in science and conduct the reviews described above. NSF also assesses risk related to subaward monitoring during its pre-award reviews, specifically for proposals of $10M and greater. Advanced pre-award reviews are handled by expert cost analysts within DIAS, and NSF also utilizes expert advice of outside sources as warranted.

NSF has recently undergone an OIG audit of the agency's monitoring of recipients managing subawards. The OIG stated that "in most cases, NSF's processes for monitoring grantees were sufficient to ensure that pass-through entities monitored subrecipients properly." The audit report recommended that NSF strengthen several policies and procedures to better align with the *Uniform Guidance* (2 CFR § 200) as it relates to subrecipient compliance. NSF agreed with all OIG recommendations, has already acted on several issues, and intends to take additional actions to address all recommendations in the audit report pursuant to a corrective action plan.

Based on NSF's risk-based evaluation of this process, coupled with the extensive OIG audit of this area, NSF believes that the residual risk to the agency is low and is consistent with NSF's low risk appetite for misuse of funds and non-compliance with reporting and performance requirements. NSF is confident that its current pre- and post-award processes adequately consider and balance risk, resources, and stewardship.

NSF's Anticipated Milestones

- Revise DIAS's Subrecipient Review module to require review of awardee compliance with 2 CFR § 200.331 by October 2018.
- Revise the DIAS Over-$10M SOG to align with 2 CFR § 200 as it relates to the agency's responsibility to oversee its prime recipients managing subawards by October 2018.
- Revise the BSR Guide to align with 2 CFR § 200 as it relates to the agency's responsibility to oversee its prime recipients managing subawards by November 2018.
- Revise the Large Facilities Manual to align with 2 CFR § 200 as it relates to the agency's responsibility to oversee its prime recipients managing subawards by June 2019.
- Revise the "DACS/CSB Standardized Cost Analysis Guidance" to align with 2 CFR § 200 as it relates to the agency's responsibility to oversee its prime recipients managing subawards by September 2018.

Management of the IPA Program
Co-Leads: Assistant Director, BIO and Office Head, OIRM

Summary of OIG Identified Challenge

(a)	(b)	(c)	(d)
Because individuals can serve in a temporary capacity for up to four (4) years, there is frequent turnover in staff at NSF, especially in senior leadership positions.	The amount of time IPAs spend on Independent Research/Development (IR/D) at their home institution raises concern about the ability of IPAs to fulfill their responsibilities at NSF and to be fully engaged in the agency's mission.	NSF's reliance on IPA's comes at an added cost because IPAs are not subject to Federal pay and benefits limits. The American Innovation and Competitiveness Act (AICA) requires a report on NSF's efforts to control costs associated with IPAs.	NSF could strengthen some of its internal controls to improve NSF's ability to identify and or mitigate IPA conflicts of interest.

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years

(a)	– Established an ongoing culture of staff development to ensure that there is a "bench" of staff ready for developmental detail assignments in the event that there are vacancies in executive positions, to include the Federal Executive Institute (FEI), American University Executive Leadership Program, Harvard Business School Leadership Training, Individual Development Plans, and NSF Academy training activities. – Developed and implemented a new employee onboarding program, the New Executive Transition Program (NeXT) in 2009 (NSF has historically held new employee onboarding sessions that include IPAs). The NeXT program supports the onboarding of employees and IPAs transitioning into executive-level positions. The program provides a comprehensive set of tools and information to help new executives reach full performance as quickly as possible by developing executive knowledge about NSF mission, culture, organization, people, and business processes. The NeXT Program currently includes a three-day Executive Leadership Retreat and a one-day Oversight of Merit Review, which applies to most executive IPAs. NSF also offers executive coaching to help IPAs and all executives understand their new roles and navigate the Federal environment. – Instituted mandatory and optional training for Program Officers, who comprise a large proportion of IPAs, on NSF's Merit Review process which teaches how research proposals are evaluated and how to execute the Program Officer role. There is a Merit Review Basics series (MRB I through MRB IV), and the first two modules have been required since 2011 and the remaining two are optional. NSF is in the process of changing the requirement to include all four one-day modules. There is also an optional two-day capstone workshop called the Program Management Seminar which is typically taken by a majority of Program Officers (including IPAs). – Created a parallel performance management system in 2014 for IPAs to ensure clarity in setting expectations and providing feedback on performance. – Established a knowledge transfer process in 2015, by which exiting executives can transfer key pieces of knowledge and information to incoming executives. – Implemented a required three-day supervisory training and development course in 2015 called Federal Supervision at NSF designed to assist new federal supervisors (including IPAs) in understanding their roles and all of the requirements pertaining to federal human capital management.

	– Established a Steering Committee for Policy and Oversight of the IPA Program (IPA Steering Committee) in April 2016 to serve as the primary body for considering policy on NSF's use of IPAs, and to oversee common approaches to budgeting and implementation of the IPA program. A key responsibility of the Steering Committee is to develop and track metrics related to the use of IPAs.
(b)	• Established an IR/D Council in October 2011 to develop and monitor internal controls related to the IR/D program, including tracking the time spent on IR/D activities. Data from these internal controls are disseminated to NSF senior management quarterly, for use in managing the IR/D program within each organization. • Developed an IR/D Guide in 2012 to clearly communicate NSF policies on the use of IR/D, including the possibility that participation in the IR/D program could be curtailed if it compromised the completion of NSF duties. • Designated IR/D experts in each Directorate/Office who receive annual training to ensure that NSF policies are implemented appropriately. • Instituted a requirement that all IR/D plans provide an explanation of how the IR/D activities enhance the requestor's ability to perform NSF duties. • Published a revised IR/D Guide in January 2017 that includes guidance limiting NSF payment of IPAs' IR/D travel to their home institutions to 12 trips per year. The guidance encourages IPAs to combine other NSF official business and/or telework with these trips to get the most efficient use of those travel dollars.
(c)	• Completed an IPA Steering Committee analysis of costs associated with the IPA program in FY 2016 and determined that the incremental cost of the program (i.e., computing the cost differential if the positions held by IPAs were instead filled with federal employees) was approximately $5M (or 0.07% of the NSF budget). Proportionally, this cost differential only nominally increases the total IPA program costs. As part of this analysis, the IPA Steering Committee did identify opportunities for potential cost savings, and NSF in turn initiated a pilot requiring 10% cost sharing by IPAs' home institutions of their academic-year salaries and fringe benefits (per NSF Bulletin 16-11). This pilot applies to all new IPA agreements initiated in FY 2017 and beyond, including those for executive and program level staff. Additionally, NSF eliminated reimbursement for lost consulting. • Designed and began data collection for an evaluation led by the NSF Office of Integrated Activities Evaluation and Assessment Capability to determine the cost implications associated with the 10% cost sharing pilot and the extent to which the policy change impacts NSF's ability to recruit strong IPAs. • Received notice from the OIG closing the sole open audit recommendation related to IPA costs as a result of these efforts. Recommendation closed in February 2017.
(d)	• Continued to apply the same suitability, credentialing, and security vetting process for employees and IPAs alike, and to require IT security and privacy training for all employees and IPAs for physical and logical access to facilities and systems. • Continued to implement NSF's long-standing policy with respect to statutory and perceived conflicts of interest (COIs) for staff and reviewers. Staff who manage the merit review process are required to take training on the agency's ethics rules. These policies and requirements apply to all staff, including IPAs. • Formulated a corrective action plan in response to the OIG's recommendations to strengthen and add to existing controls as cited in its June 2017 audit report, *NSF Controls to Mitigate IPA Conflicts of Interest*. The report concluded that NSF had "implemented internal controls to identify and mitigate IPA conflicts of interest." • Issued a memorandum (OD 17-03) in March 2017 to all staff, including IPAs, reminding them of the importance of high ethical standards. NSF also issued a notice to supervisors in August 2017

	(OD 17-17), reminding them of their ethics responsibilities, specifically the responsibility to ensure that all subordinates, including IPAs, comply with the agency's ethics rules. • Reviewed and updated core policies relating to IPAs in the NSF Personnel Manual. • Developed a required online ethics training module for all new employees, including IPAs.

Actions Taken in FY 2018

(a)	• Conducted analysis (January 2018) on IPA years of service and found that, on average, IPA executives serve 3.1 years at NSF (January 2018) and are 3 times more likely to stay for 3-4 years compared to staff-level IPAs. Non-executives serve, on average, 2.3 years at NSF. Per OPM, the average time a career SES spends in a position is 3.4 years and non-career SES is 1.7 years.[2] • Engaged with the GAO on an inquiry into the turnover of IPAs. NSF embraces IPA turnover as it helps enable NSF to keep pace with rapidly changing scientific advancements. NSF makes every effort to match those changes with a continuous cycle of deep scientific expertise and strong ties to the scientific community. The short-term nature of the rotator tenure allows NSF to continuously renew and align resources to our core mission requirement to promote the progress of science.
(b)	• Delivered the IR/D Annual Report to NSF Deputy Assistant Directors (DADs) (November 2017) indicating, on average, 72% of IPAs participated in IR/D, down from 76% two years ago. On average, IPA IR/D plans requested 37 days of IR/D, yet only 19 days were used. As of October 2017, active IR/D plans for IPAs totaled $1.36M in dollars requested with an expected actual spend of approximately $680,000. • Delivered a "Benefits of the NSF IR/D Program" report to the DADs (March 2018), highlighting the value of IR/D in recruitment, research currency, and ethics protection. IPAs participating in IR/D are at the forefront of the research landscape and impact merit review decisions using the latest knowledge, thus having a direct impact on the NSF mission.
(c)	• Extended the Cost-Share Pilot into FY 2018 to continue to evaluate the effectiveness of the 10% cost-share requirement. An evaluation of the effectiveness of the IPA Cost-Share Pilot that was launched for FY 2017 indicated that there was a cost-share percentage increase from 7.2% in FY 2016 to 7.9% in FY 2017, resulting in an average cost-share increase of almost $5,000 per IPA assignment. • Engaged with the GAO on the salary reimbursements associated with IPAs. NSF does not set the salaries for rotators who are detailed to NSF using the IPA authority, as their salaries are set by their home institutions. • Submitted to Congress responses to the American Innovation and Competitiveness Act of 2017 (P.L. 114-329) (AICA), Section 111 (Personnel Oversight), regarding the Justifications for Rotator Pay Exceeding the SES Pay Max; and Evaluation of the Cost-sharing Pilot (January 2018).
(d)	– Clarified NSF Policy (*Proposal & Award Policies & Procedures Guide*) requiring a substitute negotiator on proposals submitted by former NSF staff, including IPAs, for one year after their departure. – Addressed the corrective actions associated with the OIG audit NSF Controls to Mitigate IPA Conflicts of Interest (17-2-008). Three of the four recommendations in the corrective action plan have been closed by the OIG.

NSF Management's Overview of the Challenge

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

[2] https://www.opm.gov/policy-data-oversight/senior-executive-service/facts-figures/#url=Demographics

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 areas. In fact, many of these rotators remain involved in their professional research and development activities while working at NSF through participation in the IR/D program, which is managed by the NSF IR/D Council.

NSF takes a proactive approach in the management of the IPA program to appropriately consider and mitigate inherent risks associated with its execution.

Demonstrated Top Leadership Commitment:
The IPA Steering Committee reports directly to NSF Director France A. Córdova and Chief Operating Officer (COO) F. Fleming Crim and has been in place since April 2016. The IPA Steering Committee comprises senior-level leadership across the agency, namely a Chair who is part of the agency's Senior Executive Service (SES), the Chairs of the NSF Executive Resources Board (ERB) and IR/D Council, Head of the Office of Diversity and Inclusion, and four at-large members, including two SES and two executive-level IPAs.

The IPA Steering Committee is charged with ensuring NSF is best utilizing the IPA hiring authority. It advises the Foundation's senior leadership on matters that directly concern policy on the use of the IPA program, and on common approaches to budgeting and implementation of the program. It also regularly reports on its oversight and stewardship of the IPA program, including costs associated with the program, to the Director and COO; to OMB; and to Congress, pursuant to the AICA.

Capacity:
The IPA Steering Committee is supported in the execution of its responsibilities by various NSF units with key expertise for risk management, reporting, and accountability, including BFA, the OIRM Division of Human Resource Management, the Office of General Counsel, the Office of Legislative and Public Affairs, and the Office of Integrative Activities.

Corrective Action Plan:
With this support, the IPA Steering Committee is pursuing an enterprise risk management approach to identify and understand the potential risks associated with the IPA program, the inherent impacts and likelihood of these risks, the risk reduction steps being undertaken to address these risks, and the residual risk impacts and likelihood. As part of this approach, and given the management challenges identified by OIG, four risks have been identified: frequent turnover in staff, particularly in senior leadership positions; the time that IPAs spend away from NSF, e.g., as part of their IR/D activities; internal controls associated with IPAs' conflicts of interest; and the costs associated with the IPA program.

NSF has addressed the corrective action plan associated with the most recent OIG audit on NSF Controls to Mitigate IPA Conflicts of Interest (17-2-008). Three of the four recommendations in the corrective action plan have been closed by the OIG. NSF has successfully closed all recommendations from previous OIG audits and reviews of the IPA program.

Monitoring:
Coupled with rigorous data capture, analysis, and sharing across the agency, the IPA Steering Committee is now enabling rigorous decision making to improve directional oversight for the management of the program. For example, the IPA Steering Committee analyzed the costs of the IPA program, identified potential areas for cost savings, and pursued implementation of these approaches. Additionally, it led the design and data collection effort for an evaluation of the associated policy implementation, in conjunction with NSF's Evaluation and Assessment Capability within OIA.

Demonstrated Progress:
Based on the above, NSF has taken several steps to further strengthen the IPA program. The NSF Director issued a memorandum to all NSF staff, including IPAs, in March 2017 reminding them of the importance of high ethical standards (Staff Memorandum OD 17-03); and a separate notice to supervisors, in August 2017, reminding them of their ethics responsibilities, specifically the responsibility to ensure that their subordinates, including IPAs, comply with agency ethics rules (Staff Memorandum OD 17-17). Further, the IPA Steering Committee recommended, and NSF adopted, the initiation of a pilot requiring 10% cost-sharing by every IPA's home institution of the IPA's academic-year salary and fringe benefits (per NSF Bulletin 16-11), which applies to all new IPA agreements initiated in FY 2017, including those for executive- and program-level staff. NSF has also ended support for lost consulting payments and, in January 2017, published a revised IR/D Guide that includes guidance limiting NSF payment of IPAs' IR/D travel to their home institutions to 12 trips per year. This encourages IPAs to combine other NSF official business and/or telework with these trips to get the most efficient use of those travel dollars. Pending the basis for an evaluation of these changes, particularly the cost-sharing pilot, NSF extended the pilot through FY 2018.

NSF is therefore constantly improving its management of the IPA program and addressing the management challenges identified by the OIG as well as other agency-identified risks and challenges. In this way, NSF is ensuring the program fully supports the mission of the agency and the nation's interests. Indeed, NSF believes that the steps taken to date and described above have reduced the inherent risk substantially, such that the residual risk is acceptable to the agency.

<u>NSF's Anticipated Milestones</u>

(a)	(b)	(c)	(d)
• Deliver the first IPA Program Annual Report to the Director of NSF. This report will provide annual data and trend analyses on various aspects related to the use of IPAs at NSF, for use by the Director and NSF senior managers in assessing and overseeing the program. • Develop the CAP in response to the GAO report, "A Workforce Strategy and Evaluation of Results Could Improve Use of Rotating Scientists, Engineers, and Educators" (GAO-18-533).	Monitor time spent on IR/D by both permanent and rotating staff, and provide data to NSF senior managers to ensure appropriate oversight of IR/D.	• Develop the year two cost-share pilot evaluation report for submission to the IPA Steering Committee and the Office of the Director. • Submit to Congress responses to the American Innovation and Competitiveness Act (P.L. 114-329) (AICA), Section 111 (Personnel Oversight), regarding the Justifications for Rotator Pay Exceeding the SES Pay Max; and Evaluation of the Cost-share Pilot.	Implement an electronic separation clearance process that tracks completion of the OGC ethics exit interviews where separating staff will acknowledge their responsibility for being familiar with post-employment restrictions.

U.S. Antarctic Program (USAP) Management
Co-Leads: Assistant Director, GEO, and Office Director, Polar Programs

Summary of OIG Identified Challenge

(a)	(b)	(c)	(d)
Ensure a successful transition from Lockheed Martin to Leidos as the Antarctic Support Contractor (ASC) together with their respective subcontractors by having strong cost controls to protect the government against unwarranted increases in ASC costs during a period of reorganization and mergers.	Continue to coordinate with the ASC to soundly manage the acquisition and shipment of Antarctica-bound inventory stored and maintained at Port Hueneme, California; Punta Arenas, Chile; and Christchurch, New Zealand.	Ensure modernization of McMurdo Station as it proceeds to construction under the Antarctic Infrastructure Modernization for Science (AIMS) project by obtaining the necessary funding from Congress, capitalizing on lessons learned from NSF's large facility work as appropriate, and minimizing the impact that the AIMS planning and construction process will have on Antarctic science.	Continue to address misconduct in the Antarctic as set forth in the 2015 OIG Report, Audit of Health and Safety in the U.S. Antarctic Program.

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years

(a)	– Held routine executive meetings with Lockheed Martin leadership to understand the strategic rationale for the transition to Leidos and the impact to the ASC. – Began implementing the novation agreement processed by the Defense Contract Management Agency (DCMA) as the cognizant Federal Agency, which concluded that restructuring was in the best interest of the government. • Monitored Leidos' operations on legacy Lockheed Martin systems. The Accounting System, Estimating System, Material Management and Accounting System, Purchasing System, and Property System were approved by DCMA in a letter dated August 25, 2016.
(b)	– Conducted two detailed root cause analyses in response to early fiscal year (FY) 2017 failures, followed by process improvements. NSF directed the ASC to develop reports on the damaged science equipment and mishandled science samples explaining how and why the damage occurred, and to implement corrective actions to avoid such damage in the future. NSF then approved the action plans and monitored contractor activity for effectiveness. • Modified contract policy so that going forward, senior ASC management will be directly involved in all high value-science sample shipments to ensure minimum risk. Final approval for shipment must come from the senior transportation manager. • Ensured that appropriate mitigation for the risk of loss or damage was implemented by November 2016.
(c)	• Continued progress on the 2012 Blue Ribbon Panel (BRP) recommendations, including investment in lifecycle acquisitions and infrastructure upgrades. • Addressed major infrastructure upgrades recommended by the BRP report for McMurdo Station through the following design efforts: – Completed designs for the Antarctic Infrastructure Modernization for Science (AIMS) project, including Core Facility and Utilities packages, and presented the designs to the MREFC Preliminary Design Review (PDR) Panel. – Completed designs of the Vehicle Equipment/Operations Center using NSF Research and Related Activities Funding.

	– Continued design on the Information Technology & Communications (IT&C) Primary Operations Center, Lodging, and Palmer Pier Replacement Projects. – Completed presentation to the National Science Board (NSB), which resulted in the NSB's recommendation that the NSF Director or her designee include the AIMS project in a future budget request. – Completed ~ $2M in infrastructure investments in the Black Island Telecommunications Facility to address BRP Recommendation 4.7-5, Black Island Telecommunications Facility risk management. – Issued a Sources Sought Notice on FBO.gov to apprise potential offerors on the AIMS project. • Continued internal coordination with LFO in order to leverage institutional knowledge pertaining to previous large facilities work, including best practices and considerations outlined in NSF's *Large Facilities Manual* (NSF 17-066).
(d)	• Code of Conduct: Developed a process for reporting and reviewing Code of Conduct violations, which states that each year the Office of Polar Programs will send a request to all USAP employing organizations and NSF's on-site representatives (for grantees) for a report of all significant instances of on ice misconduct for the previous 12 months. **This audit action item (#1) regarding the USAP Code of Conduct was formally closed by the OIG on March 28, 2017.** • Law Enforcement: – Oversaw NSF's law enforcement program's achievement of full compliance with all U.S. Marshals Service requirements for certification and training, and recommendations for law enforcement tools made by the Service. – Initiated planning for a future site visit to Antarctica, resources and schedules permitting. OPP had internal conversations with OGC and reached out to law enforcement organization contacts. • Breathalyzer Testing: – Procured breathalyzer units that do not require calibration. These units provide redundancy for the existing breathalyzer inventory. **This audit action sub-item (#4.2) regarding breathalyzer calibration was formally closed by the OIG on 12/22/2015.)** – Continued 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 being planned.

Actions Taken in FY 2018

(a)	• Monitored the transfer of business systems from Lockheed Martin to Leidos. Subsequently, the Leidos DCMA Divisional Administrative Contracting Officer reviewed and approved Leidos business systems. • Continued to monitor invoices, Annual Program Plans, business system reviews (accounting, estimating, purchasing systems), indirect rates and financial reporting for the USAP contractor to ensure strong cost controls continue with the new entity.
(b)	• Directed NSF's annual assessment of ASC performance, which will identify cargo failures and contractor responses. Emphasis will be placed on opportunity costs of mishandled science samples and replacement costs of damaged inventory. Penalties will be considered in the contractor award fee. • Continued to monitor cargo shipments during the August 2017 - February 2018 cycle. • Conducted weekly NSF-led meetings with the prime contractor focused on protecting government property.

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Authorized additional design to advance the AIMS design beyond bridging documents (35%). Initiated and completed necessary initial solicitation efforts for individual AIMS components.
Completed designs for and awarded IT&C Primary Addition for construction.
Initiated acquisition of major components of the Ross Island Satellite communications Earth Station (RIES) to address Black Island Telecom Facility deficiencies.
Prepared for AIMS Final Design Review (FDR), anticipated in Q1 of FY 2019.
Continued to update the long-range capital plan to include lifecycle and real property investments for all Antarctic locations.
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<u>Code of Conduct</u>:

Continued to implement NSF process for reporting and reviewing Code of Conduct violations.
Updated Code of Conduct to clarify to the community the consequences (e.g., potential removal) of misconduct in Antarctica.

<u>Law Enforcement</u>:

Reviewed the final report dated March 12, 2018 of a group of law enforcement officials who had conducted an on-site evaluation in February 2018. The Law Enforcement Review and Site-Visit assessed equipment and training for special deputies and reviewed other areas, such as legal jurisdiction, USAP law enforcement staffing, facilities, communications with the U.S. Marshals Service, and detainment and transportation of suspects. The report contains recommendations and suggestions. This audit action item (#3) regarding USAP Law Enforcement was formally closed by the OIG on June 12, 2018.

<u>Breathalyzer Testing</u>:

Finalized a memo detailing the results of NSF exploration of the advisability and feasibility of implementing a requirement for breathalyzer testing for all USAP participants. NSF determined that since USAP supporting organizations have their own breathalyzer testing programs, the benefit of establishing and enforcing an NSF-managed breathalyzer program would not be worth the legal, contractual and financial obligations. NSF decided to accept the risk of not implementing its own breathalyzer program. This audit action sub-item (#4.1) regarding the legality of requiring breathalyzer testing for all USAP participants was formally closed by the OIG on 02/05/2018.)

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<u>NSF Management's Overview of the Challenge</u>

NSF—through the Office of Polar Programs (OPP) in the Directorate for Geosciences (GEO)—funds and manages the U.S. Antarctic Program (USAP). The USAP supports United States' research and national policy goals in the Antarctic. The inherent risks associated with Antarctica's remote location, extreme environment, and the short period of time during which the continent is accessible has precipitated several actions under the USAP management challenge for NSF. These actions include: a) ensuring a successful transition from Lockheed Martin to Leidos as the Antarctic Support Contractor (ASC) while preventing unwarranted increases in cost; b) ensuring sound management of the acquisition and shipment of Antarctica-bound property and inventory stored and maintained at three ports—Port Hueneme, California, Punta Arenas, Chile, and Christchurch, New Zealand; c) ensuring modernization of McMurdo Station as it proceeds to construction under the Antarctic Infrastructure Modernization for Science (AIMS) project; and d) continuing to address misconduct in the Antarctic, including items noted in the 2015 OIG Report, *Audit of Health and Safety in the U.S. Antarctic Program*.

Through leadership commitments, dedication of staff and resources, corrective action planning, and monitoring implementation of plans, NSF has demonstrated significant progress in reducing the inherent risk to residual risk levels for USAP management that are well within acceptable ranges. The transition of the ASC responsibilities to Leidos has occurred without disruptions in operations or unwarranted increases in cost. Management controls and operating procedures for monitoring invoice processing and systems performance are in place. Efforts are underway to evaluate an automated process to review invoices and identify inaccuracies. NSF performed root cause analyses of issues pertaining to the shipment and storage of property and inventory, and consequently developed and implemented process improvements. Routine NSF-led meetings are held with Leidos to emphasize prime contractor responsibilities to protect government property. Planning and implementation of the modernization of McMurdo Station and other large facilities work in Antarctica are underway with cognizance by the National Science Board (NSB), the Office of Management and Budget (OMB), and Congress. Plans going forward include engaging the scientific community in efforts to minimize disruption that the AIMS planning and construction process might have on Antarctic science. NSF has dedicated staff with primary responsibility of stewardship for the long-range capital plan, to include lifecycle and real property investments for all Antarctic locations. All 2015 OIG misconduct-related action items, as expressed in the *Audit of Health and Safety in the U.S. Antarctic Program*, were closed by the OIG. NSF and USAP efforts have been positive steps and continuing efforts will help ensure USAP is well poised to address misconduct in the future.

NSF's Anticipated Milestones

(a)	(b)	(c)	(d)
• Continue to apply invoice processing in accordance with the current NSF "Guidance and Instructions for Invoice Review and Processing" SOP. • Evaluate an automated process to review invoices and identify inaccuracies.	• Monitor cargo during the upcoming shipment cycle (August 2018 - February 2019). • Continue to conduct weekly NSF-led meetings with the prime contractor focused on protecting government property.	• Complete necessary solicitation efforts for AIMS project. • Conduct AIMS Final Design Review (FDR) in Q1 of FY 2019. • Engage the scientific community in efforts to minimize disruption that the AIMS planning and construction process might have on Antarctic science. – Advance the long-range capital plan to include lifecycle and real property investments for all Antarctic locations.	– Code of Conduct: – Continue to implement its process for reporting and reviewing Code of Conduct violations. – Continue to update the Code of Conduct as circumstances required. • Law Enforcement: – Implement appropriate changes in response to the Federal Law Enforcement Site Visit Report.

Cybersecurity and IT Management
Lead: Chief Information Officer

Summary of OIG Identified Challenge

(a)	(b)	(c)
System Monitoring: Protect information systems against unauthorized access or modification to decrease the risk of unauthorized transactions and unauthorized changes to data, audit logs, and configurations that remain undetected and affect the integrity of financial transactions.	USAP IT Security: Allocate appropriate resources to correct IT weaknesses related to the U.S. Antarctic Program (USAP) and ensure the systems and information are adequately protected.	Mobile Devices: Develop effective measures to preserve social media messages, capture text messages on NSF-owned devices, and monitor downloads of smartphone applications to ensure compliance with Federal requirements and guidance for electronic records management.

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years

(a)	(b)	(c)
• Continued monitoring activities to comply with the Federal Information Security Modernization Act (FISMA) and ensured ongoing operational security throughout the system lifecycle. • Implemented numerous risk mitigating actions in FY 2017 to address the OIG's management challenges. • Established configuration baselines for productions systems and implemented the Department of Homeland Security Continuous Diagnostics and Mitigation (CDM) program Phase I with more frequent configuration scans. • Documented user administration processes for the Award System and webTA.	Adjusted the USAP security plan review and updated process to provide earlier updates to validate controls being in place for the year.	Implemented a mobile device management (MDM) capability to enforce configuration management and ensure the integrity of agency information.

Actions Taken in FY 2018

(a)	(b)	(c)
• Established technical controls to monitor the NSF network for unauthorized access to reduce the risk of unauthorized transactions, changes to data, audit logs and configurations. • Conducted configuration scans and regular reviews of audit logs and reported results to management. • Proactively assessed the security state of systems through NSF's IT security continuous monitoring program.	• Allocated appropriate resources to the USAP IT security program to address FISMA findings. • Completed security plan updates and a business impact analysis to address recovery priorities.	• Updated and issued guidance related to the use of smartphone applications that support encryption and/or automatically delete messages. • Implemented controls in May 2018 that prohibit applications identified as violating NSF policy from being downloaded onto NSF-issued mobile devices. • Prohibited applications that support encrypted communication unless their use is approved by the OGC and NSF Records Officer per federal guidance. • Implemented quarterly monitoring of applications.

NSF Management's Overview of the Challenge

The availability of information technology (IT) resources and security posture of its IT systems is vital to NSF's ability to carry out its mission. The agency's Chief Information Officer is part of the Office of the Director and oversees the Foundation's proactive IT security management structure that takes a risk-based approach and provides timely and relevant information to stakeholders. The agency has assessed the risks in the three areas set forth in the OIG Management Challenge for Cybersecurity and Information Technology Management and is confident that overall the residual risks remaining are low.

As of July 2018, NSF analyzed the root causes, e.g. people, process and tools, and agency staff implemented solutions to address the three challenges noted above. NSF senior management established and committed to a Plan of Action and Milestones (POA&M) as a performance measure to monitor corrective action progress. The POA&M incorporates the IG Management Challenges for systems monitoring, USAP IT security, and mobile devices. The POA&M is updated quarterly, and a progress report is distributed to senior management for review.

Systems Monitoring. NSF established a system-wide audit log review process by implementing procedures and tools to monitor the system and report results to senior management on a regular basis. While NSF acknowledges the potential impact of unauthorized activity on agency systems, based on these actions and the above described evaluation of this risk, causes and outcomes, NSF is confident that the remaining residual risk is low.

USAP IT Security. The Office of Polar Programs (OPP), U.S. Antarctic Program (USAP) Section for Antarctic Infrastructure and Logistics (GEO/OPP/AIL) prioritized IT security initiatives and committed resources to address FISMA findings. Specifically, GEO/OPP/AIL conducted a Business Impact Analysis (BIA) to identify mission and business processes, prioritize the processes, and determine the impact on the processes if systems are unavailable. The OPP BIA identifies important functional relationships and interdependencies, as well as time sensitivities that impact the USAP mission. OPP implemented the National Institute of Standards and Technology Risk Management Framework to enable GEO/OPP/AIL to prepare, execute, and communicate in keeping with cybersecurity risk management best practices. OPP's risk-based approach to cybersecurity is supported by operational activities, regular program reviews and management reporting that support risk decisions and risk mitigation actions. Through improved oversight and resource allocation to priority tasks, OPP continues to manage the residual risk for USAP information systems.

Monitoring and reporting processes communicate cybersecurity risk to senior management to assess risk and determine appropriate courses of action consistent with organizational risk tolerance. The IT security program is evaluated in accordance with the FISMA. NSF is proactive in reviewing security controls and identifying areas to improve the IT security program and incorporates information gained and lessons learned to strengthen NSF's cybersecurity posture. NSF's adaptive risk management is very responsive to a changing cybersecurity environment with low residual risk.

Mobile Devices. In addition to ensuring the availability and strong security posture of agency IT systems, NSF recognizes the importance of protecting the integrity of information on, and appropriate use of, NSF-issued mobile devices. Part of this responsibility is ensuring that information on agency mobile devices, including smartphones and tablets, is captured and retained per Federal recordkeeping requirements. NSF's mobile device management capability enforces configuration requirements on mobile devices that access NSF email, contacts, and calendars, and provides mechanisms to ensure compromised devices are disconnected from agency systems so information is not lost. Additionally, NSF has implemented new procedures and controls which allow specific applications to be blacklisted, preventing their use on NSF-issued mobile devices. NSF has blacklisted two mobile applications that support encryption and/or the ability to automatically delete messages after they are read or sent, which could be used to circumvent agency recordkeeping systems. NSF is monitoring installed applications on agency-issued mobile devices each quarter to identify if there are new applications that should be restricted from use. Furthermore, NSF continues to research alternatives for the automatic capture and retention of text messages on NSF-issued mobile devices and plans to have this capability in place by November 2018.

In addition to the technical controls previously described, NSF continues to educate mobile device users on their responsibilities for ensuring the capture and retention of information mobile devices per Federal records management guidance. In May 2018, the Foundation published a revised NSF Bulletin related to the assignment and use of agency mobile devices, including more detailed information on protecting and preserving agency information. The May 2018 NSF Bulletin revision updated the rules of behavior outlining responsibilities for individuals with NSF-issued mobile devices. With recent and planned actions related to NSF's mobile device services program, comprising technology controls and policy guidance, there is low residual risk of loss for electronic records requiring capture and retention. NSF continues to evaluate its mobile device services program offerings to focus on the intersection between users and technologies, with the goal of protecting agency information against loss or disclosure.

<u>NSF's Anticipated Milestones</u>

(a)	(b)	(c)
Employ capabilities to further strengthen the cybersecurity program and implement application event monitoring tools and audit log reviews to detect potential unauthorized changes to financially significant data or configuration changes that affect NSF's security process.	• Maintain OPP operational IT security awareness, review program priorities, and allocate resources to ensure IT security program infrastructure and staffing requirements are adequate. • Ensure OPP's NextGen project addresses IT infrastructure upgrades.	• Continue to research alternatives for the automatic capture and retention of text messages on NSF-issued mobile devices and plans to implement this capability by November 2018. • Continue to evaluate additional enhancements to NSF mobile device services program, including new capabilities to preserve information and ensure the retention of agency electronic messaging and information per federal guidance.

Encouraging the Ethical Conduct of Research
Lead: Chief Operating Officer

Summary of OIG Identified Challenge

(a)	(b)	(c)
It is essential that NSF continue to recognize the importance of its Responsible Conduct of Research (RCR) requirement. It is important to emphasize research integrity as a core value.	*NSF awardees could benefit from NSF providing written guidelines or templates for universities to follow. NSF has an opportunity to encourage incorporation of best practices into RCR programs.*	*NSF should encourage institutions to extend their RCR programs to faculty.*

NSF's Key Actions to Address the Challenge
Agency Actions Taken in Prior Fiscal Years
Issued Important Notice No. 140, Training in Responsible Conduct of Research – A Reminder of the NSF Requirement from the NSF Director on August 17, 2017.

Actions Taken in FY 2018

(a)	• Evaluated themes and common threads of research misconduct cases and used the analysis to draft additional guidance for the FY 2019 Proposal and Award Policies and Procedures Guide (PAPPG) on the definition and consequences of research misconduct and on NSF-funded resources available for RCR training. • Revised Cultivating Cultures for Ethical STEM (CCE STEM) program solicitation to incorporate specific references to RCR training and online resources to assist with RCR training. • Sponsored an SBE special lecture at NSF, "Fighting against Doubt and Promoting Public Trust in Research Practices", presented by Kristen Intemann. • Emphasized integrity as a core value in the NSF strategic plan, *Building the Future: Investing in Discovery and Innovation*, by specifically stating that "We hold each other and our awardees to the highest standards of ethical behavior. We strive to ensure the trustworthiness of the results of NSF-funded research by promoting the responsible conduct of research." • Included RCR requirement in NSF outreach at the NSF Grants Conference and other outreach events.
(b)	• Incorporated a reference to Chapters 9 ("Identifying and Promoting Best Practices for Research Integrity") and 10 ("Education for the Responsible Conduct of Research") of *Fostering Integrity in Research* (National Academies of Sciences, Engineering, and Medicine, 2017) (NASEM Report) into the draft PAPPG scheduled for publication in October 2018. • Encouraged awardees to incorporate promising RCR practices by initiating outreach regarding proposed PAPPG changes. • Revised the CCE STEM program solicitation to incorporate the *Fostering Integrity in Research* conclusion that "training for responsible conduct of research is most effective when it is part of a comprehensive approach to enhance an organization's research enterprise." • Synthesized a set of findings regarding best ethical research practices based on reports from three of the ethics workshops NSF funded over the past three years. • Held meeting with CCE STEM PIs to review synthesized workshop findings and receive input on dissemination plans.
(c)	• Produced a set of slides on RCR and research misconduct for use in NSF staff outreach to the research community, suggesting that STEM faculty incorporate RCR into their mentoring, teaching, and curriculum development. • Held NSF senior management briefings about the importance of involving PIs and Co-PIs in the RCR requirement.

	• Drafted guidance language for the FY 2020 PAPPG: "NSF encourages training of faculty in the responsible and ethical conduct of research."

NSF Management's Overview of the Challenge

NSF leadership emphasizes that NSF does not tolerate research misconduct, which means fabrication, falsification, or plagiarism in proposing or performing research funded by NSF, in reviewing research proposals submitted to NSF, or in reporting research results funded by NSF. The OIG investigates allegations of research misconduct and makes recommendations to NSF for disposition. NSF's Chief Operating Officer decides on disposition of the referrals for research misconduct based on input from staff in the Office of General Counsel, the Office of Integrative Activities, and the Office of the Director. In 2017, the NSF Director issued an Important Notice reminding NSF awardees of the NSF requirement for training in responsible conduct of research, and NSF's strategic plan for FY2018-2022 emphasizes integrity as a core value. As reported by the OIG in its Spring 2017 Semiannual Report, the number of research misconduct referrals to NSF from FY 2005 through FY 2017 has remained relatively low and has not trended upward. NSF also performed a more detailed root cause analysis of referrals to the agency by the OIG in FY 2016 and FY 2017. In this 2-year period, NSF made 23 findings of research misconduct based on 24 referrals (excluding referrals arising from the Small Business Innovation Research/Small Business Technology Transfer programs). Nine of the findings arose from plagiarism by faculty in proposals to NSF that were not funded. Considering that the total number of referrals by the OIG is relatively low and NSF reviewed over 98,000 proposals and funded over 23,000 proposals in the same period, it is difficult to identify trends. However, NSF notes that a significant subset of findings involve plagiarism by faculty in unfunded proposals. NSF is addressing these issues through additional guidance and outreach. NSF will continue to track and analyze the OIG's investigation referrals to assess responsive actions and identify new trends. NSF recognizes the potential high impact of research misconduct and has taken actions to reduce the likelihood of such activities.

NSF's Anticipated Milestones

(a)	(b)	(c)
Publish the 2019 PAPPG with the additional language on the definition and consequences of research misconduct and on the NSF-funded resources available for RCR training.	• Continue to fund the Online Ethics Center and research on best practices. • Incorporate workshop findings into the Online Ethics Center. • Hold a "promising practices summit" conference with examples of effective RCR approaches. • Publish revised PAPPG incorporating a reference to Chapters 9 ("Identifying and Promoting Best Practices for Research Integrity") and 10 ("Education for the Responsible Conduct of Research") of the NASEM report. • Continue to encourage awardees to incorporate promising RCR practices by initiating outreach regarding new PAPPG changes.	• Use the new outreach materials for encouraging faculty to participate in RCR training and demonstrate best practices. • Encourage STEM faculty to incorporate RCR in their mentoring, teaching, and curriculum development.

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 is also advised by external committees on specific topics. Recent examples include: 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 four 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-fourth of NSF's divisions are assessed each year.

A COV typically consists of up to 20 external experts, selected to ensure independence, programmatic coverage, and geographic balance. COV members come from academia, industry, government, and the public sector. They meet for two or three days to review and assess program priorities, program management, and award accomplishments or outcomes. Each COV prepares a report and the division or program that is being reviewed must prepare a response to the COV recommendations. These reports and responses are submitted to the parent advisory committee and to the Director of NSF. All reports and responses are public and posted on NSF's website.[1]

In FY 2018, five directorates or offices convened nine COVs, covering all or part of seven divisions and one office. A table of the COVs performed in recent years and planned through FY 2020 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. A list of the evaluations completed in FY 2018 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.

[1] www.nsf.gov/od/oia/activities/cov/covs.jsp

External Evaluations Completed in FY 2018 and the first quarter of FY 2019

DIR	Name of Evaluation	Evaluator	Link to report
CISE	Growth of Computer Science Undergraduate Enrollments	National Academies	www.nap.edu/catalog/24926/assessing-and-responding-to-the-growth-of-computer-science-undergraduate-enrollments
CISE	Data Science for Undergraduates: Opportunities and Options	National Academies	www.nap.edu/catalog/25104/data-science-for-undergraduates-opportunities-and-options
CISE	Quantum Computing: Progress and Prospects (published FY 2019)	National Academies	www.nap.edu/catalog/25196/quantum-computing-progress-and-prospects
ENG	Environmental Engineering for the 21st Century: Addressing Grand Challenges (published FY 2019)	National Academies	www.nap.edu/catalog/25121/environmental-engineering-for-the-21st-century-addressing-grand-challenges
GEO	Science Engineering and Education for Sustainability Portfolio Evaluation	Manhattan Strategy Group	Not public. See OIA and GEO narratives.
GEO	Geoscience Education Evaluation	2M Research	Not public. See OIA and GEO narratives.
SBE	Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine	National Academies	www.nap.edu/catalog/24994/sexual-harassment-of-women-climate-culture-and-consequences-in-academic
SBE	Measuring the 21st Century Science and Engineering Workforce Population: Evolving Needs	National Academies	www.nap.edu/catalog/24968/measuring-the-21st-century-science-and-engineering-workforce-population-evolving

List of Committees of Visitors Meetings, FY 2015-FY 2020

DIR	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019 (planned)	FY 2020 (projected)
BIO	Environmental Biology (DEB)	Biological Infrastructure (DBI)	-	Molecular and Cellular Biosciences (MCB) Integrative Organismal Systems (IOS)	DEB	DBI
CISE	Computing and Communication Foundations (CCF) Computer and Network Systems (CNS) Information and Intelligent Systems (IIS)	-	-	Advanced Cyberinfrastructure	-	CCF CNS IIS
EHR	Research on Learning in Formal and Informal Settings (DRL) Graduate Education (DGE): GK-12/ IGERT/SFS Undergraduate Education (DUE): ATE DUE: Noyce/S-STEM	-	Human Resource Development (HRD) EHR Core Research DUE: TUES, STEP, WIDER, IUSE: EHR	-	DGE DUE	DRL HRD
ENG	Chemical, Bioengineering, Environmental and Transport Systems (CBET) Civil, Mechanical and Manufacturing Innovations (CMMI)	Engineering, Education and Centers (EEC) Industrial Innovation and Partnerships (IIP)	-	Electrical, Communications and Cyber Systems (ECCS) Emerging Frontiers and Multidisciplinary Activities	CBET CMMI	EEC IIP

DIR	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019 (planned)	FY 2020 (projected)
GEO	Atmospheric and Geospace Sciences (AGS): NCAR and Facilities Ocean Sciences (OCE): Research and Education	AGS: Atmosphere Section (AS)	Education and Diversity Programs Earth Sciences (EAR)	AGS: Geospace OCE: Integrative Programs	AGS: Facilities OCE: Research Programs	AGS: multiple programs
MPS	Astronomy (AST) Materials Research (DMR) Physics (PHY)	Chemistry (CHE) Mathematical Sciences (DMS)	-	-	AST DMR PHY	CHE DMS
SBE	Office of Multidisciplinary Activities (SMA) Behavioral and Cognitive Sciences (BCS)	Social and Economic Sciences (SES)	-	-	SMA BCS	SES
OPP, OIA, and OISE	Established Program to Stimulate Competitive Research (EPSCoR)	Major Research Infrastructure (MRI) Office of Polar Programs (OPP): Antarctic Sciences OPP: Arctic Sciences	-	International Science and Engineering National Academies: Board on International Science Organizations	-	EPSCoR MRI OPP: Antarctic Sciences OPP: Arctic Sciences

Data Verification and Validation

It is NSF's practice to follow Government Accountability Office (GAO) guidance and engage external contractors to conduct an independent validation and verification (V&V) review of its annual performance information, data, and processes. The guidance from GAO indicates that agencies should "…describe the means the agency will use to verify its performance data…" and "…provide confidence that [their] performance information will be credible."[2]

In FY 2018, NSF contracted with Nexight Group to perform the independent verification and validation. Nexight assessed the validity of NSF data and verified the reliability of the methods used to collect, process, maintain, and report that data. Nexight's FY 2018 report concluded:

> The Nexight Team was able to verify the reliability of the processes used to generate the performance measure results for seven performance goals. Although some of the measures have issues that should be addressed in future years, the data collection processes for all measures adhere to the five V&V criteria—Complete, Consistent, Accurate, Timely, and Valid—and are sufficient to ensure that the results are usable. The Nexight Team was also able to confirm the reported results for most of the performance measures under the seven goals.
>
> Overall, the Nexight Team verifies that NSF relies on sound data collection practices, internal controls, and manual checks of system queries to ensure accurate performance reporting. Based on the V&V assessment, the Nexight Team has confidence in the systems, policies, and procedures used by NSF to calculate results for its performance measures. NSF continues to take concerted steps to improve the quality of its systems and data. The Nexight Team confirms NSF's commitment to ensuring the accuracy of its reported Government Performance and Results Act (GPRA) results, and the reliability of its processes for collecting, processing, maintaining, and reporting data for its performance goals.[3]

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. Data requests of external parties. Qualitative or quantitative information is solicited directly from awardees.

[2] GAO, The Results Act: An Evaluator's Guide to Assessing Agency Annual Performance Plans, GAO/GGD-10.1.20 (Washington, D.C.: April 1998), pp. 40-41.
[3] Nexight Group with Energetics Incorporated, *National Science Foundation Performance Measurement Verification and Validation Report, Fiscal Year 2018*. November 2018.

3. 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.

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.

TECHNICAL INFORMATION

FY 2020 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; $5,662,960,000, to remain available until September 30, 2021, 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, $823,470,000, to remain available until September 30, 2021.

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, $223,230,000, 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; $336,890,000: *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 2020 for maintenance and operation of facilities and for other services to be provided during the next fiscal year.

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General as authorized by the Inspector General Act of 1978, $15,350,000, of which $400,000 shall remain available until September 30, 2021.

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.), $4,100,000: *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 504 of this Act and shall not be available for obligation except in compliance with the procedures set forth in that section.

SUMMARY OF FY 2020 BUDGETARY RESOURCES BY ACCOUNT
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted	FY 2020 Request	Change Over FY 2018 Actual Amount	Change Over FY 2018 Actual Percent
RESEARCH AND RELATED ACTIVITIES						
Appropriation	$6,350.78	$6,334.48	$6,520.00	$5,662.96	-$687.82	-10.9%
Unobligated Balance Available Start of Year	33.89	24.49	24.49		-33.89	
Unobligated Balance Available End of Year	-24.49				24.49	
Adjustments to Prior Year Accounts[3]	20.20				-20.20	
Subtotal, R&RA	**$6,380.38**	**$6,358.97**	**$6,544.49**	**$5,662.96**		
Transfer to/from other funds						
Total Budgetary Resources	**$6,380.38**	**$6,358.97**	**$6,544.49**	**$5,662.96**	**-$717.42**	**-11.3%**
EDUCATION AND HUMAN RESOURCES						
Appropriation	$902.00	$902.00	$910.00	$823.47	-$78.53	-8.7%
Unobligated Balance Available Start of Year	7.66	14.26	14.26		-7.66	
Unobligated Balance Available End of Year	-14.26				14.26	
Adjustments to Prior Year Accounts[3]	8.47				-8.47	
Subtotal, EHR	**$903.87**	**$916.26**	**$924.26**	**$823.47**		
Transfer to/from other funds						
Total Budgetary Resources	**$903.87**	**$916.26**	**$924.26**	**$823.47**	**-$80.40**	**-8.8%**
MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION						
Appropriation	$182.80	$182.80	$295.74	$223.23	$40.43	22.1%
Unobligated Balance Available Start of Year	31.36	28.43	28.43		-31.36	
Unobligated Balance Available End of Year	-28.43				28.43	
Adjustments to Prior Year Accounts[3]	0.57				-0.57	
Subtotal, MREFC	**$186.30**	**$211.23**	**$324.17**	**$223.23**		
Transfer to/from other funds						
Total Budgetary Resources	**$186.30**	**$211.23**	**$324.17**	**$223.23**	**$36.94**	**17.5%**
AGENCY OPERATIONS AND AWARD MANAGEMENT						
Appropriation	$328.51	$328.51	$329.54	$336.89	$8.38	2.6%
Unobligated Balance Available Start of Year	0.41	0.19	0.19		-0.41	
Unobligated Balance Available End of Year	-0.19				0.19	
Adjustments to Prior Year Accounts[3]	-0.22				0.22	
Subtotal, AOAM	**$328.51**	**$328.70**	**$329.73**	**$336.89**		
Transfer to/from other funds						
Total Budgetary Resources	**$328.51**	**$328.70**	**$329.73**	**$336.89**	**$8.38**	**2.5%**
NATIONAL SCIENCE BOARD						
Appropriation	$4.37	$4.37	$4.37	$4.10	-$0.27	-6.2%
Unobligated Balance - Expired	-0.07				0.07	
Total Budgetary Resources	**$4.30**	**$4.37**	**$4.37**	**$4.10**	**-$0.20**	**-4.5%**
OFFICE OF INSPECTOR GENERAL						
Appropriation	$15.20	$15.20	$15.35	$15.35	$0.15	1.0%
Unobligated Balance Available Start of Year	0.39	0.40	0.40		-0.39	
Unobligated Balance Available End of Year	-0.40				0.40	
Adjustments to Prior Year Accounts[3]	-0.10				0.10	
Total Budgetary Resources	**$15.09**	**$15.60**	**$15.75**	**$15.35**	**$0.26**	**1.7%**
TOTAL DISCRETIONARY, NATIONAL SCIENCE FOUNDATION	**$7,818.43**	**$7,835.13**	**$8,142.77**	**$7,066.00**	**-$752.43**	**-9.6%**

Totals exclude reimbursable amounts.

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

[2] Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.

[3] Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

SUMMARY OF FY 2020 BUDGETARY RESOURCES BY ACCOUNT

(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted	FY 2020 Request	Change Over FY 2018 Actual Amount	Change Over FY 2018 Actual Percent
EDUCATION AND HUMAN RESOURCES, H-1B						
Appropriation, Mandatory (H1-B Non-Immigrant Petitioner Fees)	$155.99	$120.00	$120.00	$120.00	-$35.99	-30.0%
Unobligated Balance Available Start of Year	96.86	64.68	64.68		-96.86	
Sequestration Previously Unavailable	9.73	10.30	10.30	7.75	-1.98	
Sequestration Pursuant OMB M-13-06	-10.30	-7.75	-7.75	-7.75	2.55	
Unobligated Balance Available End of Year	-64.68				64.68	
Adjustments to Prior Year Accounts[3]	4.66				-4.66	
Total Budgetary Resources	**$192.26**	**$187.23**	**$187.23**	**$120.00**	**-$67.23**	**-35.9%**
DONATIONS						
Mandatory Programs (Special or Trust Fund)	$28.28	$40.00	$40.00	$40.00	$11.72	29.3%
Unobligated Balance Available Start of Year	32.62	31.76	31.76		-32.62	
Sequestration Previously Unavailable						
Sequestration Pursuant OMB M-13-06						
Unobligated Balance Available End of Year	-31.76				31.76	
Adjustments to Prior Year Accounts[3]	0.08				-0.08	
Total Budgetary Resources	**$29.22**	**$71.76**	**$71.76**	**$40.00**	**$10.78**	**15.0%**
TOTAL, NATIONAL SCIENCE FOUNDATION	**$8,039.91**	**$8,094.12**	**$8,401.76**	**$7,226.00**	**-$813.91**	**-10.1%**

Totals exclude reimbursable amounts.

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

[2] Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.

[3] Adjustments include upward and downward adjustments to prior year obligations in unexpired accounts.

NSF FY 2020 REQUEST FUNDING BY PROGRAM
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted[2]	FY 2020 Request	Change Over FY 2018 Actual Amount	Change Over FY 2018 Actual Percent
BIOLOGICAL SCIENCES (BIO)						
BIOLOGICAL INFRASTRUCTURE	$181.31	-	-	$163.16	-$18.15	-10.0%
EMERGING FRONTIERS	85.06	-	-	83.82	-1.24	-1.5%
ENVIRONMENTAL BIOLOGY	155.00	-	-	141.70	-13.30	-8.6%
INTEGRATIVE ORGANISMAL SYSTEMS	192.17	-	-	168.93	-23.24	-12.1%
MOLECULAR & CELLULAR BIOSCIENCES	143.05	-	-	125.75	-17.30	-12.1%
TOTAL, BIO	**$756.60**	**-**	**-**	**$683.36**	**-$73.24**	**-9.7%**
COMPUTER & INFORMATION SCIENCE & ENGINEERING (CISE)						
ADVANCED CYBERINFRASTRUCTURE	$224.24	-	-	$199.02	-$25.22	-11.2%
COMPUTING & COMMUNICATION FOUNDATIONS	195.63	-	-	172.93	-22.70	-11.6%
COMPUTER & NETWORK SYSTEMS	231.88	-	-	205.73	-26.15	-11.3%
INFORMATION & INTELLIGENT SYSTEMS	210.69	-	-	189.51	-21.18	-10.1%
INFORMATION TECHNOLOGY RESEARCH	98.36	-	-	115.85	17.49	17.8%
TOTAL, CISE	**$960.80**	**-**	**-**	**$883.04**	**-$77.76**	**-8.1%**
ENGINEERING (ENG)						
CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, & TRANSPORT SYSTEMS	$187.19	-	-	$169.43	-$17.76	-9.5%
CIVIL, MECHANICAL, & MANUFACTURING INNOVATION	236.95	-	-	204.00	-32.95	-13.9%
ELECTRICAL, COMMUNICATIONS, & CYBER SYSTEMS	116.05	-	-	105.04	-11.01	-9.5%
INDUSTRIAL INNOVATION & PARTNERSHIPS	271.71	-	-	245.25	-26.46	-9.7%
[SBIR/STTR]	*[209.98]*	-	-	*[195.15]*	*[-14.83]*	*[-7.1%]*
ENGINEERING EDUCATION & CENTERS	116.71	-	-	92.60	-24.11	-20.7%
EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES	49.28	-	-	65.10	15.82	32.1%
TOTAL, ENG	**$977.90**	**-**	**-**	**$881.42**	**-$96.48**	**-9.9%**
GEOSCIENCES (GEO)						
ATMOSPHERIC & GEOSPACE SCIENCES	$276.10	-	-	$221.97	-$54.13	-19.6%
EARTH SCIENCES	179.69	-	-	156.97	-22.72	-12.6%
INTEGRATIVE & COLLABORATIVE EDUCATION AND RESEARCH	85.75	-	-	93.20	7.45	8.7%
OCEAN SCIENCES	366.26	-	-	314.91	-51.35	-14.0%
TOTAL, GEO	**$907.80**	**-**	**-**	**$787.05**	**-$120.75**	**-13.3%**
MATHEMATICAL & PHYSICAL SCIENCES (MPS)						
ASTRONOMICAL SCIENCES	$311.16	-	-	$217.08	-$94.08	-30.2%
CHEMISTRY	246.29	-	-	214.18	-32.11	-13.0%
MATERIALS RESEARCH	337.14	-	-	273.78	-63.36	-18.8%
MATHEMATICAL SCIENCES	237.69	-	-	203.26	-34.43	-14.5%
PHYSICS	310.75	-	-	247.50	-63.25	-20.4%
MULTIDISCIPLINARY ACTIVITIES	60.39	-	-	100.02	39.63	65.6%
TOTAL, MPS	**$1,503.41**	**-**	**-**	**$1,255.82**	**-$247.59**	**-16.5%**

NSF FY 2020 REQUEST FUNDING BY PROGRAM
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted[2]	FY 2020 Request	Change Over FY 2018 Actual Amount	Change Over FY 2018 Actual Percent
SOCIAL, BEHAVIORAL & ECONOMIC SCIENCES (SBE)						
BEHAVIORAL AND COGNITIVE SCIENCES	$86.60	-	-	$78.97	-$7.63	-8.8%
SOCIAL AND ECONOMIC SCIENCES	87.05	-	-	80.58	-6.47	-7.4%
MULTIDISCIPLINARY ACTIVITIES	23.57	-	-	21.73	-1.85	-7.8%
NATIONAL CENTER FOR SCIENCE & ENGINEERING STATISTICS	53.46	-	-	48.80	-4.66	-8.7%
TOTAL, SBE	**$250.69**	**-**	**-**	**$230.08**	**-$20.61**	**-8.2%**
OFFICE OF INTERNATIONAL SCIENCE AND ENGINEERING (OISE)	**$48.98**	**-**	**-**	**$46.24**	**-$2.74**	**-5.6%**
OFFICE OF POLAR PROGRAMS (OPP)						
OFFICE OF POLAR PROGRAMS	$501.72	-	-	$403.39	-$98.33	-19.6%
[US Antarctic Logistical Support Activities]	*[71.13]*	-	-	*[71.00]*	*[-0.13]*	*[-0.2%]*
Total, OPP	**$501.72**	**-**	**-**	**$403.39**	**-$98.33**	**-19.6%**
INTEGRATIVE ACTIVITIES (IA)						
ESTABLISHED PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)	$170.59	-	-	$151.23	-19.36	-11.3%
INTEGRATIVE ACTIVITIES	300.46	-	-	339.81	39.35	13.1%
TOTAL, IA	**$471.05**	**-**	**-**	**$491.04**	**$19.99**	**4.2%**
UNITED STATES ARCTIC RESEARCH COMMISSION	**$1.43**	**-**	**-**	**$1.52**	**$0.09**	**6.3%**
TOTAL, RESEARCH AND RELATED ACTIVITIES	**$6,380.38**	**$6,334.48**	**$6,520.00**	**$5,662.96**	**-$717.42**	**-11.2%**
EDUCATION & HUMAN RESOURCES (EHR)						
GRADUATE EDUCATION	$258.34	-	-	$244.06	-$14.28	-5.5%
HUMAN RESOURCE DEVELOPMENT	162.66	-	-	178.30	15.64	9.6%
RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS	228.22	-	-	181.72	-46.50	-20.4%
UNDERGRADUATE EDUCATION	254.65	-	-	219.39	-35.26	-13.8%
TOTAL, EDUCATION & HUMAN RESOURCES	**$903.87**	**$902.00**	**$910.00**	**$823.47**	**-$80.40**	**-8.9%**
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION	**$186.30**	**$182.80**	**$295.74**	**$223.23**	**$36.93**	**19.8%**
AGENCY OPERATIONS AND AWARD MANAGEMENT	**$328.51**	**$328.51**	**$329.54**	**$336.89**	**$8.38**	**2.6%**
OFFICE OF THE INSPECTOR GENERAL	**$15.09**	**$15.20**	**$15.35**	**$15.35**	**$0.26**	**1.7%**
NATIONAL SCIENCE BOARD	**$4.30**	**$4.37**	**$4.37**	**$4.10**	**-$0.20**	**-4.6%**
TOTAL, NATIONAL SCIENCE FOUNDATION	**$7,818.43**	**$7,767.36**	**$8,075.00**	**$7,066.00**	**-$752.43**	**-9.6%**

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was locked prior to the enactment of the FY 2019 Omnibus appropriation

[2] Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.

OBJECT CLASSIFICATION
NSF Consolidated Obligations
(Dollars in Millions)

Object Class Code	Standard Title	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request
11.1	Full-time permanent	$169	-	$172
11.3	Other than full-time permanent	13	-	14
11.5	Other personnel compensation	3	-	3
11.8	Special personal service payment	42	-	42
	Total personnel compensation	**$227**	**-**	**$231**
12.1	Civilian personnel benefits	57	-	59
21.0	Travel and transportation of persons	22	-	23
23.1	Rental payments	27	-	31
23.2	Rental payments to others	2	-	-
23.3	Communications, utilities, and	-	-	3
24.0	Printing and reproduction	-	-	1
25.1	Advisory and assistance services	189	-	170
25.2	Other services	24	-	21
25.3	Purchases of goods and services from Government accounts	137	-	121
25.4	Operation and maintenance of facilities	271	-	270
25.5	Research and development contracts	8	-	8
26.0	Supplies and materials	1	-	1
31.0	Equipment	6	-	3
41.0	Grants, subsidies, and contributions	6,847	-	6,124
	Total, Direct obligations [1]	**$7,818**	**-**	**$7,066**

[1] Excludes obligations for mandatory and reimbursable accounts.

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 2018 Actual**
DEFENSE	
Air Force	$11.83
Navy	4.10
Army	4.63
Other DoD (DARPA, NSA & Intelligence)	6.49
Subtotal, DoD	**$27.05**
Agriculture	0.76
Commerce (Including Census, NOAA, & NIST)	15.97
Energy	10.21
Health & Human Services	18.49
Homeland Security	1.19
Interior	1.30
NASA	10.67
OTHER (less than $500,000)	1.86
TOTAL REIMBURSEMENTS	**$87.50**

Totals may not add due to rounding

Consistent with applicable legislation and GAO decisions, agreements include reimbursement for costs that are incurred in the management and administration of these awards.

EXPLANATION OF FY 2018 CARRYOVER INTO FY 2019 BY ACCOUNT

The National Science Foundation's (NSF) total unobligated balance of $168.60 million ($72.16 million for Discretionary accounts, including $4.39 million for Incoming Interagency Reimbursable Agreements, and $96.44 million for Mandatory accounts) is described below.

DISCRETIONARY

Within the Research and Related Activities (R&RA) account, $28.87 million (including $4.38 million in reimbursable funds) was carried over into FY 2019.

Directorate for Engineering
- Amount: $2.38 million
- Reason: SBIR Phase II to be used on SBIR Phase I or Phase II awards depending on when funds become available. The carryover amount is due to 1) the program receiving a significantly larger allocation than anticipated when early FY 2018 decisions were being made, and 2) the conversion of SBIR/STTR operations costs to "outside the target costs." This mid-year change increased available SBIR/STTR award funding by an additional $5.0 million.
- Obligation: FY 2019 Quarter 2

Directorate for Mathematical and Physical Sciences (R&RA No-Year funding)
- Amount: $12.30 million
- Reason: Arecibo Observatory Hurricane Maria Relief Funding.
- Obligation: Anticipated FY 2019 Quarter 3 (The proposal for Hurricane Maria repairs will be submitted to AST in mid-March. Funds are expected to be fully obligated in FY 2019.)

Integrative Activities
- Amount: $542,310
- Reason: Funds to support Proposal Management Efficiencies contracts that were not ready for obligation in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Integrative Activities for Convergence Accelerator
- Amount: $3.94 million
- Reason: These carryover funds will be used to fund start-up activities for the new Convergence Accelerators for Harnessing the Data Revolution for 21st-Century Science and Engineering ($1.97 million) and for the Future of Work at the Human-Technology Frontier ($1.97 million).
- Obligation: Anticipated FY 2019 Quarter 4

Integrative Activities for Program Planning and Policy Development
- Amount: $500,000
- Reason: These carryover funds will be used to co-fund a Growing Convergence Research proposal from the GCR prospectus/proposal cycle beginning in October 2018. (Funds were initially reserved to co-fund an invited GCR RAISE proposal from the FY 2018 cycle, but that proposal was subsequently recommended for declination by the review panel.)
- Obligation: Anticipated FY 2019 Quarter 4

National Coordination Office for Networking and Information Technology Research and Development

- Amount: $316,840
- Reason: Operational funds are needed to continue government procurements and operations.
- Obligation: Anticipated FY 2019 Quarter 3

National Nanotechnology Coordination Office

- Amount: $126,602
- Reason: NNCO's carryover will be used to fund the required Quadrennial Review of the National Nanotechnology Initiative. In addition, funds carried over will be used to cover rent in NNCO's new location and other operational costs.
- Obligation: Anticipated FY 2019 Quarter 2

The remaining R&RA carryover of $4.39 million consists of funds from throughout the Foundation for selected projects that were not ready for obligation in FY 2018.

Within the <u>Education and Human Resources (EHR)</u> account, $14.27 million (including $9,347 in reimbursable funds) was carried over into FY 2019.

Excellence Awards in Science and Engineering

- Amount: $3.63 million
- Reason: These carryover funds will be used to recognize recipients of the Presidential Awards for Excellence in Mathematics and Science Teaching and recipients of the Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring.
- Obligation: Anticipated FY 2019 Quarter 2

The remaining $10.63 million of unallotted no-year funds will be used for awards supporting STEM teacher education associated with the Robert Noyce Teacher Scholarship Program and the EHR Core Research program.

Within the <u>Major Research Equipment and Facilities Construction (MREFC)</u> account, $28.43 million was carried over into FY 2019.

Regional Class Research Vessels

- Amount: $17.0 million
- Reason: FY 2017 appropriation exceeded project requirements and unobligated FY 2018 budget contingency.
- Obligation: Anticipated FY 2019 Quarter 3; and combined with FY 2019 funding to exercise option on the third hull.

Large Synoptic Survey Telescope

- Amount: $4.74 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Daniel K. Inouye Solar Telescope

- Amount: $3.46 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 4

National Ecological Observatory Network
- Amount: $1.42 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 3

Dedicated Construction Oversight
- Amount: $1.24 million
- Reason: Budget contingency funding not obligated in FY 2018.
- Obligation: Anticipated FY 2019 Quarter 4

The remaining $570,000 consists of funds from selected projects that were not ready for obligation in FY 2018.

Within the Agency Operations and Award Management (AOAM) no-year component, $189,091 was carried over into FY 2019.

NSF Headquarters Relocation
- Amount: $49,191
- Reason: Resources reserved for unanticipated expenses related to the new NSF Headquarters.
- Obligation: FY 2019 Quarter 1

The remaining $139,900 consists of funds that were not ready for obligation in FY 2018.

Within the Office of Inspector General (OIG) two-year account, $400,000 was carried over into FY 2019.

Office of the Inspector General
- Amount: $400,000
- Reason: Funds are expected to be used to procure financial and forensic audit services. 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.
- Obligation: Anticipated FY 2019 Quarter 4

MANDATORY

Within the H-1B no-year account, $64.68 million was carried over into FY 2019.

Innovation Technology Experiences for Students
- Amount: $22.08 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.
- Obligation: Anticipated FY 2019 Quarter 4

Scholarships in Science, Technology, Engineering, and Mathematics
- Amount: $26.98 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.
- Obligation: Anticipated FY 2019 Quarter 4

The remaining $15.62 million consists of unallotted recoveries.

Within the Donations account, $31.76 million was carried over into FY 2019. Donations were received from foreign governments, organizations, and individuals to fund various cooperative efforts in science, research, and education.

Distribution of FY 2018 Carryover into FY 2019
Discretionary and Mandatory Accounts
(Dollars in Millions)

Discretionary Accounts	Amount
Research and Related Activities[1]	$28.87
Education and Human Resources[1]	14.27
Major Research Equipment and Facilities Construction	28.43
Agency Operations and Award Management	0.19
Office of Inspector General	0.40
Subtotal	**$72.16**
Mandatory Accounts	
H-1B Non-Immigrant Petitioner	64.68
Donations (Special or Trust Fund)	31.76
Subtotal	**$96.44**
TOTAL	**$168.60**

[1]Total includes carryover from Interagency Reimbursable Agreements.

EXPLANATION OF VARIANCE OF FY 2018 ACTUALS AND FY 2018 ENACTED

Explanation of Variance of FY 2018 Actuals and FY 2018 Enacted

(Dollars in Millions)

					Explanation of Variance: FY 2018 Actuals vs. FY 2018 Enacted			
	FY 2018 Enacted Level	FY 2018 Actuals	FY 2018 Actuals change over FY 2018 Enacted Amount	Percent	Supplemental Appropriation	Obligations From Prior Year Appropriations	Recoveries and Other Adjustments	Unobligated Funds Carried Over to FY 2019
Research and Related Activities	$6,334.48	$6,380.38	$45.90	0.7%	$16.30	$44.25	$9.84	-$24.49
Education and Human Resources	902.00	903.87	1.87	0.2%	-	5.53	10.60	-14.26
Major Research Equipment and Facilities Construction	182.80	186.30	3.50	1.9%	-	-	31.93	-28.43
Award Management and Agency Operations	328.51	328.51	-0.00	0.0%	-	0.30	-0.11	-0.19
Office of Inspector General	15.20	15.09	-0.11	-0.7%	-	0.39	-0.10	-0.40
National Science Board	4.37	4.30	-0.07	-1.7%	-	-	-0.07	-
Total, National Science Foundation	**$7,767.36**	**$7,818.43**	**$51.07**	**0.7%**	**$16.30**	**$50.47**	**$52.07**	**-$67.77**

Totals exclude reimbursable obligations

In the FY 2020 NSF Budget Request, the amounts shown in the column labeled FY 2018 Actuals represent the actual obligations that occurred in FY 2018. These amounts include the obligation of prior year appropriations and other adjustments, and are therefore different from the FY 2018 Enacted Level. The sources of the variation are:

- Supplemental appropriation provided by Public Law 115-123.
- Obligations (of carryover) from prior year appropriations.
- Recoveries and other adjustments.
- Unobligated funds carried over to the next 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 2017 appropriation. Funding for Polar Programs, Robert Noyce Teacher Scholarship Program, and Major Research Equipment and Facilities Construction activities have no-year funding, so additional obligations in FY 2018 could also be associated with earlier years.

GOOD ACCOUNTING OBLIGATION IN GOVERNMENT ACT (GAO-IG ACT) REPORT

Pursuant to P.L. 115-331, the Good Accounting Obligation in Government Act, the following three tables report on outstanding NSF OIG and GAO recommendations and their associated status as of March 2019.

Table 1: Open OIG Recommendation - Internal Audits

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Timeline for Final Implementation
15-2-009	USAP Health and Safety (7/2/2015)	2.1. We recommend that NSF ensure that LM develop and implement a solution to its pharmacy tracking system.	Resolved	NSF has procured the software for the pharmacy tracking system, which is projected to be implemented by December 1, 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	1. Ensure NSF allows sufficient time to conduct a thorough and robust assessment of the agency's susceptibility to improper payments.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	2. Add a quantitative approach for IPERA risk assessments to gain insight on how NSF funds are used by awardees and assess whether both primary and secondary payments were proper.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	3. Document the policies and procedures to be followed during the IPERA risk assessment and require staff and contractors to follow these policies and procedures.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	4. Discuss all relevant OMB risk factors with the relevant leadership and staff, including a cross-section of those responsible for making and managing individual awards, from NSF's Divisions and Offices responsible for the program and activities under IPERA.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	5. Clarify with NSF staff being interviewed for IPERA the meaning of inherent risk as it relates to the IPERA program and activities, and ensure that the assessment of this risk factor includes an analysis of the nature of the programs/activities and their recipients, as well as anything else that might make NSF uniquely susceptible to improper payments.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	6. Utilize OIG investigation findings, as well as NSF's own internal reports (including BSRs, site visits, and desk reviews), to identify risks associated with improper payments.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF’s compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Timeline for Final Implementation
16-3-005	IPERA Act for FY15 (5/12/2016)	7. Include a thorough review of payments to employees in the IPERA risk assessment.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF's compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
16-3-005	IPERA Act for FY15 (5/12/2016)	8. Clearly document the crosswalk between any leveraged internal control test work conducted under OMB Circular A-123 and the IPERA risk assessment and include that crosswalk in the risk assessment.	Resolved	Corrective actions completed. In 2016, the OIG determined NSF's compliance with IPERA and the OIG will be determining the status of audit recommendations in 2019.
17-2-007	Audit of NSF Conference Spending (11/4/2016)	1.1 Require the directorates and offices to submit actual costs and NSF paid attendance data and to use this updated information when preparing the OMB M-12-12 report for issuance by January 31 of each year.	Resolved	In view of the Consolidated Appropriations Act of 2019, which included language updating public reporting requirements for conference, NSF developing updated Corrective Action plan; expected implementation date is September 30, 2019
17-2-007	Audit of NSF Conference Spending (11/4/2016)	2.1. Revise the NSF Bulletin No. 14-05, Conference Planning, Approval and Reporting Requirement to include detailed guidelines on what conference costs should be compiled and reported.	Resolved	In view of the Consolidated Appropriations Act of 2019, which included language updating public reporting requirements for conference, NSF developing updated Corrective Action plan; expected implementation date is September 30, 2019.
17-2-007	Audit of NSF Conference Spending (11/4/2016)	2.2. In the revised NSF Bulletin No. 14-05, instruct directorates and offices to require contractors to separately list labor costs for each reportable conference, or require that the directorates/offices use separate task orders to get accurate cost data for the conference.	Resolved	In view of the Consolidated Appropriations Act of 2019, which included language updating public reporting requirements for conference, NSF developing updated Corrective Action plan; expected implementation date is September 30, 2019.
17-2-007	Audit of NSF Conference Spending (11/4/2016)	3.1. Update NSF Bulletin No. 14-05 to: (a) require that hotel and other receipts must be obtained and reviewed even if a contractor is used, and (b) stress closer scrutiny of Meals and Incidental Expenses charges in expense reports for NSF travelers.	Resolved	In view of the Consolidated Appropriations Act of 2019, which included language updating public reporting requirements for conference, NSF developing updated Corrective Action plan; expected implementation date is September 30, 2019.
17-2-007	Audit of NSF Conference Spending (11/4/2016)	3.2. Consider developing best practices guidance for directorates and offices for managing conference planning to minimize inappropriate, unnecessary, and wasteful spending. At the minimum, this guide should include better planning efforts to avoid hotel attrition charges.	Resolved	In view of the Consolidated Appropriations Act of 2019, which included language updating public reporting requirements for conference, NSF developing updated Corrective Action plan; expected implementation date is September 30, 2019.

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Timeline for Final Implementation
17-2-009	Audit of Preservation of Electronic Records and Cooperation with Congressional Requests (7/6/17)	2. Develop policies, procedures, and controls to capture and retain work-related text messages, social media posts, and electronic records created on government and nongovernment accounts to meet NARA requirements.	Resolved	Projected implementation date is April 30, 2019
17-2-009	Audit of Preservation of Electronic Records and Cooperation with Congressional Requests (7/6/17)	4. Develop policies and procedures related to downloading smartphone applications, including applications that encrypt emails or automatically delete messages or emails, on NSF-issued mobile devices, as required by NARA guidance.	Resolved	While NSF has partially implemented the recommendation, full implementation is pending resolution of the conflict between the OIG recommendation related to the WhatsApp application and U.S Department of State guidance.
17-3-003	NSF's Relocation to its New Headquarters Location — Records Management (9/28/17)	3. Continue working with various divisions to update their record schedules and send them to NARA for approval.	Resolved	Projected implementation date is September 30, 2019.
17-3-004	Review of NSF's Monitoring of the Battelle Memorial Institute Awards (NEON) (5/12/17)	1.1 Developing policies and procedure for NSF's use of management reserve.	Resolved	Projected implementation for guidance on management reserve is April 2019.

[1] "Resolved" status indicates where NSF and OIG have agreed upon the appropriate corrective action to address the recommendation but where implementation is ongoing or closing of the

Table 2: Open OIG Recommendations - External Audits

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Date Resolved	Costs Questioned	Costs Disallowed	Costs Allowed	Timeline for Final Implementation
16-1-004	University of Washington (2/11/2016)	1.1) Repay $1,824,117 of questioned senior salaries.	Under Resolution by NSF		$1,824,117			5/31/2019
16-1-004	University of Washington (2/11/2016)	1.2) Strengthen controls over senior salaries.	Under Resolution by NSF		-			5/31/2019
16-1-004	University of Washington (2/11/2016)	2.1) Resolve $122,893 questioned equipment, materials, and supplies costs.	Under Resolution by NSF		$122,893			5/31/2019
16-1-004	University of Washington (2/11/2016)	2.2) Strengthen controls over equipment, materials, and supplies.	Under Resolution by NSF		-			5/31/2019
16-1-004	University of Washington (2/11/2016)	3.1) Resolve $36,240 of questioned purchase card transaction costs.	Under Resolution by NSF		36,240			5/31/2019
16-1-004	University of Washington (2/11/2016)	3.2) Strengthen controls over purchase card transactions charging costs to awards.	Under Resolution by NSF		-			5/31/2019
16-1-004	University of Washington (2/11/2016)	4.1) Resolve $8,821 of questioned promotional and interest costs.	Under Resolution by NSF		$8,821			5/31/2019
16-1-004	University of Washington (2/11/2016)	4.2) Strengthen controls over unallowable costs such as promotional items.	Under Resolution by NSF		-			5/31/2019

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Date Resolved	Costs Questioned	Costs Disallowed	Costs Allowed	Timeline for Final Implementation
16-1-004	University of Washington (2/11/2016)	5.1) Resolve $6,648 of preaward costs questioned.	Under Resolution by NSF		$6,648			5/31/2019
16-1-004	University of Washington (2/11/2016)	5.2) Strengthen controls over preaward purchases.	Under Resolution by NSF		-			5/31/2019
16-1-004	University of Washington (2/11/2016)	6.1) Resolve $2,650 of questioned meal expenditures.	Under Resolution by NSF		$2,650			5/31/2019
16-1-004	University of Washington (2/11/2016)	6.2) Strengthen controls over approving meal expenditures.	Under Resolution by NSF		-			5/31/2019
16-1-004	University of Washington (2/11/2016)	7.1) Resolve $1,740 of questioned travel costs occurring after award expiration.	Under Resolution by NSF		$1,740			5/31/2019
16-1-004	University of Washington (2/11/2016)	7.2) Strengthen controls over travel near or after award expiration.	Under Resolution by NSF		-			5/31/2019
17-1-003	Purdue University (3/20/2017)	1.1) Work with NSF to resolve the $36,437 of questioned costs.	Under Resolution by NSF		$36,437			6/30/2019
17-1-003	Purdue University (3/20/2017)	1.2) Strengthen the controls and processes for travel expenditures.	Under Resolution by NSF		-			6/30/2019
17-1-003	Purdue University (3/20/2017)	2.1) Work with NSF to resolve the $28,984 of questioned costs.	Under Resolution by NSF		$28,984			6/30/2019
17-1-003	Purdue University (3/20/2017)	2.2) Strengthen the controls and processes for supplies.	Under Resolution by NSF		-			6/30/2019
17-1-003	Purdue University (3/20/2017)	3.1) Work with NSF to resolve the $25,011 of questioned costs.	Under Resolution by NSF		$25,011			6/30/2019
17-1-003	Purdue University (3/20/2017)	3.2) Strengthen the controls and processes for equipment, materials and supplies.	Under Resolution by NSF		-			6/30/2019
17-1-003	Purdue University (3/20/2017)	4.1) Work with NSF to resolve the $849 of questioned costs.	Under Resolution by NSF		$849			6/30/2019
17-1-003	Purdue University (3/20/2017)	4.2) Strengthen the controls and processes for unsupported costs.	Under Resolution by NSF		-			6/30/2019
17-1-010	University of Arizona	1.1) Repay the $39,770 of questioned subaward costs.	Resolved	2/12/2019	$39,770	-	$39,770	Resolved
17-1-010	University of Arizona (10/3/2017)	1.2) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
17-1-010	University of Arizona (10/3/2017)	2.1) Repay the $12,196 of questioned compassional leave costs	Resolved	2/12/2019	$12,196	$12,196	-	Resolved
17-1-010	University of Arizona (10/3/2017)	2.2) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
17-1-010	University of Arizona (10/3/2017)	3.1) Repay the $3,529 of questioned travel costs.	Resolved	2/12/2019	$3,529	$3,529	-	Resolved

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Date Resolved	Costs Questioned	Costs Disallowed	Costs Allowed	Timeline for Final Implementation
17-1-010	University of Arizona (10/3/2017)	3.2) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
17-1-010	University of Arizona (10/3/2017)	4.1) Repay the $859 of questioned preaward costs.	Resolved	2/12/2019	$859	$859	-	Resolved
17-1-010	University of Arizona (10/3/2017)	4.2) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
17-1-010	University of Arizona	5.1) Repay the $550 of questioned gym fee costs.	Resolved	2/12/2019	$550	$550	-	Resolved
17-1-010	University of Arizona (10/3/2017)	5.2) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
17-1-010	University of Arizona (10/3/2017)	6.1) Strengthen the administrative and management controls.	Resolved	2/12/2019	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	1.1) Resolve the $172,030 of unallowable costs incurred near the end of award periods.	Resolved	10/10/2018	$172,030	$32,542	$139,488	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	1.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	2.1) Resolve $91,484 of unallowable travel costs.	Resolved	10/10/2018	$91,484	$76,955	$14,529	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	2.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	3.1) Resolve the $42,054 of unallowable participant support costs.	Resolved	10/10/2018	$42,054	$42,054	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	3.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	4.1) Ensure the $13,047 of unallowable costs due to ACM$ error is removed.	Resolved	10/10/2018	$13,047	$13,047	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	4.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	5.1) Resolve $8,838 of unallowable costs that were not prudent for the awards charged.	Resolved	10/10/2018	$8,838	$7,461	$1,377	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	5.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	6.1) Resolve the $1,596 of unallowable costs made 90 days prior to award effective date.	Resolved	10/10/2018	$1,596	$1,596	-	Resolved
18-1-001	University of Kansas Research Center (10/19/2017)	6.2) Strengthen the administrative and management controls.	Resolved	10/10/2018	-	-	-	Resolved

OIG Number	Title (Final Audit Report Date)	OIG Recommendation	Status of Recommendation[1]	Date Resolved	Costs Questioned	Costs Disallowed	Costs Allowed	Timeline for Final Implementation
18-1-001	University of Kansas Research Center (10/19/2017)	7.1) Ensure that KUCR's current effort reporting activities are in compliance with Federal regulations.	Resolved	10/10/2018	-	-	-	Resolved

[1] "Under Resolution by NSF" status indicates where management decisions are pending additional documentation and NSF analyses given complex issues identified in the audit.

Table 3: GAO Open Recommendations over 1 Year as of March 2019

GAO Number	Title (Final Audit Report Date)	GAO Recommendation	Status of Recommendation	Timeline for Final Implementation
GAO-16-511	Information Technology Agencies Need to Improve Their Application Inventories to Achieve Additional Savings (09/29/2016)	Recommendation 17: To improve federal agencies' efforts to rationalize their portfolio of applications, the Secretaries of Defense, Homeland Security, the Interior, and Labor; and the Director of the National Science Foundation should direct the CIOs and other responsible officials to modify existing investment management processes to address applications more completely. Specifically, the Director of the National Science Foundation should direct the CIO to consistently document evaluations for all applications and report cost information for them in the roadmap or other documentation.	Open	The NSF has implemented this recommendation. In March 2019 the Foundation sent documentation to GAO that demonstrated that a small number of applications had been accounted for in the rationalization process. Closure of the recommendation is pending GAO review.
GAO-16-573	Federal Research Grants: Opportunities Remain for Agencies to Streamline Administrative Requirements (06/22/2016)	Recommendation 9: To further standardize administrative research requirements, the Secretary of Energy, the NASA Administrator, the Secretary of Health and Human Services, and the Director of NSF should coordinate through Office of Science and Technology Policy's (OSTP) Research Business Models working group to identify additional areas where they can standardize requirements and report on these efforts.	Open	The NSF participates in the Research Business Models (RBM) working group. The working group is finalizing the 2019 RBM Report to Congress on reducing Federal administrative and regulatory pre-award burden on extramural researchers. Once the report is complete, the RBM and its participating agencies will establish priorities for the future and continue to make advances in standardizing requirements among research agencies.

GAO Number	Title (Final Audit Report Date)	GAO Recommendation	Status of Recommendation	Timeline for Final Implementation
GAO-12-791	Organizational Transformation: Enterprise Architecture Value Needs to Be Measured and Reported (09/26/2012)	Recommendation 21: To enhance federal agencies' ability to realize enterprise architecture benefits, the Secretaries of the Departments of Agriculture, the Air Force, the Army, Commerce, Defense, Education, Energy, Homeland Security, the Interior, Labor, the Navy, State, Transportation, the Treasury, and Veterans Affairs; the Attorney General; the Administrators of the Environmental Protection Agency, General Services Administration, National Aeronautics and Space Administration, and Small Business Administration; the Commissioners of the Nuclear Regulatory Commission and Social Security Administration; and the Directors of the National Science Foundation and the Office of Personnel Management should fully establish an approach for measuring enterprise architecture outcomes, including a documented method (i.e., steps to be followed) and metrics that are measurable, meaningful, repeatable, consistent, actionable, and aligned with the agency's enterprise architecture's strategic goals and intended purpose.	Open	The NSF implemented GAO's recommendation by establishing an approach for measuring enterprise architecture outcomes. In November 2018, NSF provided GAO with supporting documentation. Closure of the recommendation is pending GAO review.
GAO-12-791	Organizational Transformation: Enterprise Architecture Value Needs to Be Measured and Reported (09/26/2012)	Recommendation 45: To enhance federal agencies' ability to realize enterprise architecture benefits, the Secretaries of the Departments of Agriculture, the Air Force, the Army, Commerce, Defense, Education, Energy, Homeland Security, the Interior, Labor, the Navy, State, Transportation, the Treasury, and Veterans Affairs; the Attorney General; the Administrators of the Environmental Protection Agency, General Services Administration, National Aeronautics and Space Administration, and Small Business Administration; the Commissioners of the Nuclear Regulatory Commission and Social Security Administration; and the Directors of the National Science Foundation and the Office of Personnel Management should periodically measure and report enterprise architecture outcomes and benefits to top agency officials (i.e., executives with authority to commit resources or make changes to the program) and to OMB.	Open	The NSF has implemented this recommendation. In November 2018, the Foundation provided evidence to GAO that it periodically measures and reports Enterprise Architecture outcomes to top agency officials. Closure of the recommendation is pending GAO review.

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE FOUNDATION
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request
Investment Activities				
Conduct of Research and Development				
Basic Research	$5,089.17	-	-	$4,530.19
Applied Research	760.28	-	-	687.06
Subtotal, Conduct of R&D	5,849.45	-	-	5,217.25
Physical Assets				
Research and Development Facilities	300.75	-	-	319.23
Research and Development Major Equipment	207.83	-	-	186.40
Subtotal, R&D Facilities & Major Equipment	508.58	-	-	505.63
Total, Research and Development	6,358.03	-	-	5,722.88
Conduct of Education and Training	700.00	-	-	617.40
Non-Investment Activities	760.40	-	-	725.72
TOTAL	$7,818.43	$7,767.36	$8,075.00	$7,066.00

QUANTITATIVE DATA TABLE

RESEARCH AND RELATED ACTIVITIES
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request
Investment Activities				
Conduct of Research and Development				
Basic Research	$4,928.06	-	-	$4,380.19
Applied Research	463.73	-	-	417.06
Subtotal, Conduct of R&D	5,391.79	-	-	4,797.25
Physical Assets				
Research and Development Facilities	114.45	-	-	96.00
Research and Development Major Equipment	207.83	-	-	186.40
Subtotal, R&D Facilities & Major Equipment	322.28	-	-	282.40
Total, Research and Development	5,714.07	-	-	5,079.65
Conduct of Education and Training	290.68	-	-	247.40
Non-Investment Activities	375.63	-	-	335.91
TOTAL	$6,380.38	$6,334.48	$6,520.00	$5,662.96

QUANTITATIVE DATA TABLE

EDUCATION AND HUMAN RESOURCES
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request
Investment Activities				
Conduct of Research and Development				
Basic Research	$161.11	-	-	$150.00
Applied Research	296.55	-	-	270.00
Subtotal, Conduct of R&D	457.66	-	-	420.00
Physical Assets				
Research and Development Facilities	-	-	-	-
Research and Development Major Equipment	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	-	-	-	-
Total, Research and Development	457.66	-	-	420.00
Conduct of Education and Training	409.31	-	-	370.00
Non-Investment Activities	36.90	-	-	33.47
TOTAL	$903.87	$902.00	$910.00	$823.47

QUANTITATIVE DATA TABLE

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 Request
Investment Activities				
Conduct of Research and Development				
Basic Research	-	-	-	-
Applied Research	-	-	-	-
Subtotal, Conduct of R&D	-	-	-	-
Physical Assets				
Research and Development Facilities	$186.30	-	-	$223.23
Research and Development Major Equipment	-	-	-	-
Subtotal, R&D Facilities & Major Equipment	186.30	-	-	223.23
Total, Research and Development	186.30	-	-	223.23
Conduct of Education and Training	-	-	-	-
Non-Investment Activities	-	-	-	-
TOTAL	$186.30	$182.80	$295.74	$223.23

QUANTITATIVE DATA TABLE

AGENCY OPERATIONS AND AWARD MANAGEMENT
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 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	$328.51	-	-	$336.89
TOTAL	$328.51	$328.51	$329.54	$336.89

QUANTITATIVE DATA TABLE

OFFICE OF INSPECTOR GENERAL
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 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	$15.09	-	-	$15.35
TOTAL	$15.09	$15.20	$15.35	$15.35

QUANTITATIVE DATA TABLE

NATIONAL SCIENCE BOARD
Research and Development Special Analysis
(Dollars in Millions)

	FY 2018 Actual	FY 2019 Annualized CR	FY 2019 Enacted	FY 2020 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	$4.30	-	-	$4.10
TOTAL	$4.30	$4.37	$4.37	$4.10