NSF FY 2019 Budget Request to Congress

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

The FY 2019 Budget Request for the National Science Foundation reflects the Administration's commitment to NSF's role in strengthening the Nation's economy, national security, and global leadership, while also restraining non-defense spending across the government. NSF funds the basic research that advances cybersecurity, infrastructure, manufacturing, and military technology, and sustains American preeminence in innovation. NSF also makes critical investments in science, technology, engineering, and mathematics (STEM) education that prepare the Nation's future-focused workforce. NSF investments have led to research that has yielded 231 Nobel prizes. Notable among these many outstanding investments is the Laser Interferometer Gravitational Wave Observatory, where gravitational waves have been detected following black hole mergers and most recently, a merger of two neutron-stars.

NSF is the only federal agency dedicated to funding basic non-biomedical research across all areas of science and engineering. NSF is also committed to the development of a future-focused science and engineering workforce that draws on the talents of all Americans. The reach of the agency's investments is broad. It is these investments that have helped sustain the U.S. role as a global leader in innovation since 1950. NSF investments drive economic growth, increase prosperity, and create jobs for the Nation and all Americans. Investments in basic and early-stage research create a foundation for breakthroughs that advance national security and preserve global leadership. The complex global and domestic challenges facing the Nation today will require NSF investments. NSF continues to increase agency efficiency and effectiveness, by improving the stewardship of multi-user facilities, seeding innovative, forward thinking convergent ideas to propel human knowledge forward into new realms, and developing additional and stronger public-private partnerships.

Scientific infrastructure has long been a cornerstone of NSF-funded research across the Nation. In FY 2019, NSF will make a strong commitment to agency supported research infrastructure. NSF will invest in the Antarctic Infrastructure Modernization for Science project, a necessity for maintaining U.S. scientific and geopolitical eminence across the continent of Antarctica. The agency will begin support for Mid-scale Research Infrastructure, an effort that will address a gap between existing research instrumentation and existing large facility funding; making more science possible while engaging more people in the pursuit of knowledge. Using funds in the Major Research Equipment and Facilities Construction account, NSF will fund the construction of two Regional Class Research Vessels, pivotal components in the modernization of the academic research fleet that helps scientists to understand numerous coastal processes.

Complementing NSF's commitment to infrastructure is the agency's constant pursuit of innovation. In FY 2019, NSF will invest in 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 decades. NSF will also initiate two Convergence Accelerators, which are new organizational structures that will leverage resources across the agency to support the most innovative science. NSF's support for the Big Ideas and the Convergence Accelerators reflects the agency's ongoing commitment to being on the cutting-edge, while supporting the fundamental research in all areas of science that has advanced the Nation since the agency's founding. Collaboration and convergence are required across NSF in order to achieve the agency's mission and support the maximum number of researchers. No longer is any one research directorate at NSF the sole NSF funder of science in a given field. Science and engineering today requires innovative approaches to leveraging resources across all fields of science.

Federal investment in basic research and the STEM workforce, led by NSF, is vital to the Nation’s continued global leadership. Other nations continue to increase their support of research, development, and STEM education, as they innovate in next-generation technologies. China and the European Union have invested significantly in quantum technology, and continue to invest billions of dollars in artificial intelligence research with an eye to a future of global leadership in these areas. There is unprecedented global competition for highly skilled, technical workers who will lead tomorrow's innovations. Continued U.S. support for basic research has never been more vital for the Nation and for the world.

NSF is essential to advancing American leadership in science and technology. NSF investments in all 50 states of the Union and all U.S. territories have resulted in both short- and long- term innovation and the robust creation of jobs. Over 50 percent of America’s economic growth of the past 50 years is attributable to technological innovation. This innovation depends on significant investment in basic research. NSF had a role in the development of the Internet, 3-D printing, cell phones, and in responding to national and international crises, including the Ebola and Zika outbreaks, the Deepwater Horizon oil spill, Hurricane Katrina, and more recently, Hurricanes Harvey, Irma, and Maria.

NSF awarded $5.30 million in 59 grants after recent natural disasters to quickly mobilize resources to aid in relief efforts, to helping understand how to better protect human lives, infrastructure, and resources during these crises. These awards helped scientists understand how to best respond to disasters in the future and how to provide immediate assistance when people needed it most. NSF investments in disaster research have advanced understanding of the paths of tropical cyclones, improved water decontamination, deployed underwater rescue robots, and helped to understand the long-term psychological and emotional effects of disasters. After hurricanes Harvey and Irma hit, researchers quickly used the NSF-funded Stampede2 supercomputer to create useful computer models that showed the likely depth and location of water in different regions, which helped first responders navigate flooded areas and allowed them to reach those most in need of assistance. Other researchers are studying the short- and long-term effects of extreme flooding in urban areas to understand the spread of diseases after floods.

Finally, NSF remains committed to investing in the basic research that helps the U.S. military both on and off the battlefield. This includes innovative military technologies to support those on the front lines. Years of NSF-funded research helped create the Worldwide-Integrated Crisis Early Warning System, which has helped the military predict where conflict is likely to break out, and how to best mitigate a potential crisis. NSF funding developed Hemogrip, a biopolymer foam that expands in a wound to minimize blood loss and save lives on the battlefield. NSF investments also work to improve the lives of veterans as they readjust to civilian life. NSF-funded research has created better prosthetics and improved screening and treatment of post-traumatic stress disorder, depression, and other issues afflicting America’s veterans.

NSF's FY 2019 Budget Request is $7.47 billion, level to FY 2017 Enacted.

NSF's 10 Big Ideas

In 2019, NSF will support 10 Big Ideas, which are bold ideas that identify areas for future, long-term investment at the frontiers of science and engineering. With its broad portfolio of investments, NSF is uniquely suited to advance this set of cutting-edge research agendas and processes that will require collaborations with industry, private foundations, other agencies, science academies and societies, and universities and other education institutions. The Big Ideas represent unique opportunities to position our Nation at the frontiers—indeed to define the frontiers—of global science and engineering leadership and to invest in fundamental research that advances America's economic competitiveness and security.

About the Big Ideas

Six of the Big Ideas focus on research, building on a foundation made possible by earlier investments in fundamental research. Four of the Big Ideas focus on process, and address NSF practices that could be altered or enhanced to capture the best research and to welcome new members to the Nation's science and engineering community.

<u>Research Big Ideas:</u>

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, i.e., its phenotype.

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

Process 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 between the $4 million cap on NSF's Major Research Instrumentation program and the $70 million lower bound for projects supported by NSF's Major Research Equipment and Facilities Construction account. 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 a long-term commitment. This Big Idea is framed around the year 2026, providing an opportunity for transformative research to mark the Nation's 250th anniversary.

Big Ideas 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 FY 2019 Budget Request to Congress will accelerate NSF's progress on the Big Ideas through the following funding models:

Research Big Ideas. An investment of $30.0 million is requested for each of the six research Big Ideas, for a total investment of $180.0 million. These investments are in addition to the significant investments already being made by individual NSF directorates and offices in these areas. This additional investment 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 multi-directorate/office leadership of the corresponding Big Idea. Budget management and reporting will be the responsibility of the directorate to which the $30.0 million is assigned for a given Big Idea, with the multi-directorate/office leadership providing oversight.

Process Big Ideas. The process Big Ideas are also emphasized in this Budget Request:

- NSF INCLUDES will be funded at $20.0 million. The program will establish the NSF INCLUDES Alliances, as NSF begins to move the NSF INCLUDES program to national-scale collaborations;
- NSF 2026 will initiate mechanisms to catalyze new research areas that may become future research Big Ideas;
- GCR will support research programs that transcend two or more of the research Big Ideas, as NSF continues to break down barriers;
- An increased investment in mid-scale research infrastructure will be used to continue to span the midscale gap noted above.

Agency Reform

The landscape in which NSF executes its mission is constantly evolving. Today's research questions are increasingly interdisciplinary in nature, requiring new levels and forms of scientific and engineering collaboration. At the same time, the Nation is addressing pressing challenges, including maintaining the security of cyber systems and physical infrastructure, building resiliency to disasters, improving Americans' health and quality of life, educating and inspiring the next-generation workforce, and growing American jobs and economic productivity. To continue to achieve its mission, NSF must therefore adapt to this evolving environment.

In support of this adaptation, and in alignment with NSF's history of continued organizational improvement and the Administration's government-wide agency reform activities, NSF will focus reforms in five areas in FY 2019:

Convergence Accelerators. These are new organizational structures that represent an evolution from how funding for research has been organized at the agency. The Convergence Accelerators will be time-limited structural entities intended to leverage external partnerships to facilitate convergent and translational activities in areas of national importance. An investment of $60.0 million in FY 2019 will support two Convergence Accelerators pursuant to two of NSF's Big Ideas for Future Investment: HDR and FW-HTF. These Big Ideas were selected for the initial Convergence Accelerators because of their readiness for convergent and translational research. The $60.0 million investment by NSF is expected to catalyze an additional $40.0 million in investment by external partners, including the private sector, other federal agencies, and international funders. The Convergence Accelerators will be launched through NSF's Office of Integrative Activities.

As noted, the funding for the Convergence Accelerators will be separate from, and in addition to, the funding for the Big Ideas. The HDR and FW-HTF Convergence Accelerators will complement HDR and FW-HTF investments by NSF directorates and offices in existing, as well as new NSF programs, that are aligned with the goals of the HDR and FW-HTF Big Ideas. These programs have laid the foundations for the HDR and FW-HTF Convergence Accelerators, and will continue to be managed by NSF's directorates and offices. By continuing, and expanding, these foundational investments, NSF will be able to enhance meaningful progress in the corresponding areas. The results of these foundational investments will in turn feed the convergent and translational activities of the Convergence Accelerators, key to the success of the overall HDR and FW-HTF Big Ideas.

Make information technology (IT) work for us. For NSF to continue funding cutting-edge science and engineering, leading-edge IT solutions that can adapt easily and quickly are essential. NSF will work to ensure that IT tools enhance employee productivity and satisfaction by enabling access, through easy-to-use interfaces, to readily available, reliable, and fully integrated data to support decision making. For example, NSF will continue efforts started under its Proposal Management Efficiency (PME) activity to automate proposal processing and improve mission-critical systems in ways that reduce workload, increase operational efficiency, and serve our clients more effectively.

In FY 2019, NSF will invest an additional $4.0 million in adoption of automated, intelligent tools that enable evolution of NSF's business processes, including its core business process of merit review; and accelerated modernization of NSF's IT infrastructure via adoption of cloud offerings, consolidated computing platforms, software-defined network infrastructure, and automated change management processes to improve overall resilience of NSF's systems.

Align NSF's workforce and work. As the Nation's research enterprise evolves and NSF's proposal volume grows, the agency's workforce stands to benefit from enhanced capabilities that advance day-to-day business processes and enable the best service to the scientific community. In parallel with the IT-enabled business process improvements described above, 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.

Expand public and private partnerships. 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, which can accelerate discovery and translation of research to products and services that benefit society and grow the American economy. NSF will improve efficiencies in developing, implementing, and managing partnerships that maximize the scientific, economic, and societal impacts of its investments. In particular, NSF will revise policies to enhance partnership development, including implementing new and innovative models with external organizations in science and engineering areas ripe for leverage. NSF will also explore additional partnerships with the private sector, philanthropies, and other federal agencies.

Streamline, standardize, and simplify programs and processes. Many NSF business processes are managed and executed locally within the agency's directorates and offices, posing efficiency and collaboration challenges. NSF will revise policies and business processes to increase standardization across NSF organizations and eliminate unnecessary complexity. There are significant opportunities for improvement relating to the merit review process, NSF's core business process, and expanded use of shared services for business operations.

Other Priorities

In FY 2019, NSF will make investments that support the basic research that advances human knowledge and make tomorrow's innovations possible. Additional investments will improve infrastructure in Antarctica, continue to protect the Nation's cyber assets, and improve artificial intelligence. In FY 2019, NSF expects that 91 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 2019, NSF expects to invest $4.92 billion dollars, or 66 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.

The **Antarctic Infrastructure Modernization for Science (AIMS)** construction project is funded at $103.70 million in FY 2019. 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. This will initiate modernization of major facilities at the aging McMurdo Station, 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 connected, enclosed buildings. AIMS will also provide necessary utilities to support these facilities. The total project cost is estimated to be $355 million, funded through the Research and Related Activities account.

Cybersecurity research ($160.55 million) protects and preserves the growing societal and economic benefits of cyber systems while ensuring preservation of individual privacy as well as usability. NSF-funded research will lead to advances in the scientific foundations underlying cybersecurity, including better understanding of the root causes of current threats and novel countermeasures to protect against them. It will also accelerate the meaningful transition to practice of cybersecurity tools and infrastructure, which will impact commercial products and policies in the long term, in alignment with the recent Presidential Executive Order on *Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure.*

NSF has long supported fundamental research on **artificial intelligence (AI)**, or the study of computers and software capable of intelligent behavior. Today, NSF-funded AI research spans many sub-areas and includes both theoretical research and its application leading to integration of new capabilities into demonstrable systems and devices. A key goal is to understand how AI-based technologies will interface with humans. For example, NSF-funded work is advancing foundational techniques such as machine learning and neural networks, as well as domain areas including reasoning and representation, speech and language understanding, vision, computational neuroscience, robotics, and human augmentation. These advances, in turn, further education through intelligent tutoring systems, increase worker productivity with cognitive and physical aids, improve health with more accurate diagnosis and prediction, and enhance highway safety through assistive controls and forthcoming autonomous vehicles.

FY 2019 NSF-Wide Investments

NSF continues to bring together researchers from all fields of science and engineering to address today's cross-disciplinary questions and challenges through Foundation-wide activities. In FY 2019, NSF will support four continuing cross-Foundation investments.

FY 2019 Funding for Ongoing NSF-Wide Investments
(Dollars in Millions)

	FY 2017 Actual	FY 2018 (TBD)	FY 2019 Request	Change Over FY 2017 Actual Amount	Change Over FY 2017 Actual Percent
Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)	$55.79	-	$16.40	-$39.39	-70.6%
NSF Innovation Corps (I-Corps™)	29.85	-	30.00	0.15	0.5%
Secure and Trustworthy Cyberspace (SaTC)	136.53	-	129.00	-7.53	-5.5%
Understanding the Brain (UtB)	159.86	-	127.20	-32.66	-20.4%

Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) ($16.40 million) aims to understand, design, and model the interconnected food, energy, and water system through an interdisciplinary research effort that incorporates all areas of science and engineering and addresses the natural, social, and human-built factors involved. INFEWS is the first program to study the interconnected food-energy-water nexus. This program is driven by pressing needs and challenges, such as growing U.S. and global populations, changes in land use, and increasing geographic and seasonal variability in precipitation patterns, all of which are placing an ever-increasing stress on these critical resources. NSF, through INFEWS, is uniquely poised to focus not only on the fundamental science and engineering questions at this nexus, but to train the next generation of researchers in this interdisciplinary area. As part of a planned decrease in activities, support for INFEWS-related research is being migrated to the Big Ideas and programs across NSF. NSF began identifying key investments explicitly as part of the INFEWS initiative in FY 2016 and will continue as planned through FY 2020. In FY 2019 ENG, GEO, IA and OISE will continue with dedicated investment, and for other directorates funding for the INFEWS emphases will continue as part of the research core investment.

NSF Innovation Corps (I-Corps™) ($30.0 million) improves NSF-funded researchers' access to resources that can assist in bridging the gap between discoveries and technologies, helping to transfer knowledge to downstream technological applications and use at scale. In FY 2019, NSF will continue to support I-Corps™ Nodes and I-Corps™ Sites to further build, utilize, and sustain a national innovation ecosystem that helps researchers effectively identify viable market opportunities and augments the development of technologies, products, and processes that benefit the Nation. NSF will also continue to support I-Corps™ Teams who are provided access to the experiential entrepreneurial education and mentoring to determine the readiness to commercialize technologies resulting from NSF-funded research.

The **Secure and Trustworthy Cyberspace (SaTC)** ($129.0 million) investment aims to build the knowledge base in cybersecurity that enables discovery, learning, and innovation, and leads to a more secure and trustworthy cyberspace. Through a focus on long-term, foundational research, SaTC will develop the scientific foundations for cybersecurity research for years to come. SaTC also focuses on the training of the next generation cybersecurity workforce, especially for government. This program aligns NSF's cybersecurity investments with the national cybersecurity strategy. While the agency's investment in SaTC will decrease slightly (-5.5 percent), NSF will maintain its investments in cybersecurity research across all related core and crosscutting programs.

Understanding the Brain (UtB) ($127.20 million) encompasses ongoing cognitive science and neuroscience research and NSF's contributions to the ongoing Brain Research through Advancing Innovation and Neurotechnologies (BRAIN) Initiative. The goal of UtB is to enable scientific understanding of the full complexity of the brain, in action and in context. There remains much to discover to attain a comprehensive understanding of the general principles underlying how cognition and behavior relate to the brain's structural organization and dynamic activities; how brain, behavior, and environment interact; and how the brain can recover from lost functionality. Investments that address critical research questions relevant to UtB are also central to the Big Ideas activities. NSF consolidated ongoing investments in cognitive science, neuroscience, and the BRAIN initiative in FY 2014 and the targeted UtB effort will continue as planned through FY 2020. BIO maintains its commitment at the FY 2017 level, and all of the other directorates involved are continuing with reduced commitments in FY 2019 as the key areas are re-aligned into the research core as well as Big Ideas such as URoL, HDR, and FW-HTF.

Education and STEM Workforce

NSF's education and STEM workforce investment, centered in the Directorate for Education and Human Resources (EHR), funds activities that support students, teachers, faculty, researchers, and the public. The EHR investment in core STEM education research is critical to building the Nation's knowledge base for strategic and impactful STEM learning. NSF's investments for FY 2019 focus on the following priorities:

The **CyberCorps®: Scholarship for Service (SFS)** program ($55.0 million) supports cybersecurity education and research at higher education institutions. SFS also focuses on workforce development by increasing the number of qualified students entering the fields of information assurance and cybersecurity, which enhances the capacity of the U.S. higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure. FY 2019 activities will include engaging first- and second-year undergraduate students, with a focus on veterans.

Computer Science for All (CSforAll) ($20.0 million) will build on ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation, to prepare the STEM workforce of the future. Funds will support the development of prototype instructional materials, scalable and sustainable professional development models, approaches to preservice preparation for computer science teachers, teacher resources, and the research to study their impact. 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 **Improving Undergraduate STEM Education (IUSE)** ($102.50 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.

Through the **Advanced Technological Education (ATE)** ($66.0 million) program, NSF is able to reach technicians in undergraduate programs preparing for the high-technology fields that drive our Nation's economy.

The **Graduate Research Fellowship Program (GRFP)** ($270.72 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. In FY 2019, NSF will support 1,500 new fellows.

Major Research Equipment and Facilities Construction

The FY 2019 Request includes funding to continue construction of the Daniel K. Inouye Solar Telescope, the Large Synoptic Survey Telescope, and the construction of two Regional Class Research Vessels. The total request to continue construction of both projects, as well as to fully fund oversight costs, is $94.95 million.

MREFC Account Funding, by Project
(Dollars in Millions)

	FY 2017 Actual	FY 2018 Request	FY 2019 Request
DKIST	$18.30	$20.00	$16.13
LSST	60.18	57.80	48.82
NEON	22.10	-	-
RCRV	121.88	105.00	28.70
Enhanced Oversight	0.33	-	1.00
Total	**$222.78**	**$182.80**	**$94.65**

The construction of **Daniel K. Inouye Solar Telescope** (DKIST) ($16.13 million) will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromosphere, and corona. It will enable scientists to study these phenomena at unprecedented spatial, temporal, and wavelength resolutions. These phenomena are associated with what is generally known as space weather, which severely impact the Nation's infrastructure. FY 2019 will be the final year of funding in an 11-year funding profile.

The **Large Synoptic Survey Telescope** (LSST) ($48.82 million) will be an 8-meter-class wide-field optical telescope capable of carrying out surveys of the entire 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 2019 will be year six of its nine-year construction funding profile.

The **Regional Class Research Vessel** (RCRV) ($28.70 million) project will fund construction of two ships. This project is a major component in the plan for modernizing the U.S. Academic Research Fleet. The RCRV will provide scientific infrastructure that enables increased understanding of: the potential impacts of geohazards, such as storm surges and tsunamis; transportation and recreation; natural resource identification and extraction; and fisheries and aquaculture, among many other topics.

Organizational Excellence

NSF seeks to integrate mission, vision, and core values to efficiently and effectively execute NSF's activities and provide the flexibility and agility required for all aspects of its operations. This goal incorporates a culture of continuous improvement to ensure effective, inclusive, and accountable programs and merit review processes that provide the greatest value for taxpayer dollars. The portfolio of activities included in Organizational Excellence addresses the agency's operations and administrative functions, which underpin NSF's programmatic activities.

Staffing

In FY 2019, NSF will work towards full utilization of its allocations of 1,442 FTE for federal staff and 168 FTE for staff hired under the Intergovernmental Personnel Act. The Foundation recognizes that maintaining staffing levels is vital to effectively and efficiently achieving its mission.

FY 2019 Summary

NSF's FY 2019 funding request for Organizational Excellence is $485.88 million, a decrease of $42.43 million, or 8.0 percent, below the FY 2017 Actual. The major reduction is in the Agency Operations and Award Management account as a result of the completion of the construction of, and relocation to, NSF's new headquarters building in Alexandria, Virginia and the lower cost of rent and utilities at the new building. Overall, Information Technology costs are relatively flat to FY 2017, and NSF will preserve secure, reliable information technology operations and continue to modernize the IT infrastructure and systems to the greatest extent funding allows. Within the Organizational Excellence portfolio in FY 2019, NSF will initiate operational reforms in four areas as discussed in the Agency Reform section of the Overview.

2018-2022 Strategic Plan and Performance

Integral to this submission is the NSF Strategic Plan for FY 2018-2022: *Building the Future: Investing in Discovery and Innovation*. The goals and strategies outlined in the plan build on lessons learned from NSF's past successes and continue to uphold NSF's mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense."

The Plan is built around three Strategic Goals:

- **Expand knowledge in science, engineering, and learning**. The first part of NSF's mission is "to promote the progress of science." By expanding human knowledge, NSF-funded researchers provide the Nation with the capability to maintain scientific, technological, and economic leadership in a competitive world.
- **Advance the capability of the Nation to meet current and future challenges**. This goal flows from the latter part of the NSF mission statement: "to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF uses a variety of approaches to promote impact-driven, use-inspired research. Innovation is a key capability for the Nation, and NSF's investments foster innovation across a broad range of topics relevant to technological and economic competitiveness.
- **Enhance NSF's performance of its mission**. Effectively fulfilling NSF's mission requires blending strong scientific leadership with robust organizational leadership. Both are characterized by vision and flexibility.

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

Agency Priority Goal: Expand Public and Private Partnerships

NSF has set an Agency Priority Goal for completion by the end of FY 2019: "Expand public and private partnerships to enhance the impact of NSF's investments and contribute to American economic competitiveness and security." By September 30, 2019, NSF's number of partnerships and/or award actions with other federal agencies, private industry, and foundations/philanthropies will grow by five percent, relative to the FY 2017 baseline, to make available infrastructure, expertise, and financial resources to the U.S. scientific and engineering research and education enterprise.

Performance Plan

NSF embraces the use of goals to drive performance improvements. For FY 2019, NSF has set performance goals to strategically monitor and oversee progress being made toward its larger aims, as well as progress towards agency reform. NSF also assesses progress through an annual process of strategic reviews of the objectives in its Strategic Plan.

In FY 2019, in addition to goals monitoring the four aspects of reform described in the next section, NSF will monitor the following longstanding goals:

- **Ensure that Key Program Investments Are on Track:** Ensure that key FY 2019 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 Award Decisions:** Inform applicants whether their proposals have been declined or recommended for funding in a timely manner.
- **Foster a Culture of Inclusion:** Foster a culture of inclusion through management efforts resulting in leadership that is committed, knowledgeable, and accountable.

Lower-Priority Program Activities

NSF's FY 2019 Request follows a thorough examination of programs and investments across NSF to determine where the potential exists for more innovative investments. This Request includes four proposed terminations, totaling $302.03 million.

Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) (-$296.25 million) was established in FY 2013 to integrate several science and engineering activities across NSF—breakthrough materials, advanced manufacturing, and smart systems, including robotic, cyber-physical, and autonomous systems. CEMMSS-funded research advanced materials with unique properties and functionality through the integration of theory, experiments, simulations, and data analytics. Further, using advanced manufacturing strategies, new materials were fashioned into objects, structures, and systems integrated with computational intelligence, thereby transforming static systems, processes, and edifices into adaptive, pervasive smart systems. CEMMSS will sunset in FY 2019 as it has achieved its programmatic goals. NSF will continue to develop several comprehensive, integrated programs across CEMMSS focus areas, such as cyber-manufacturing, advanced materials, and smart systems, including robotics, cyber-physical, and autonomous systems. These investments will encourage new cross-disciplinary connections and activities, resulting in novel discoveries and innovations with transformative societal and economic impacts.

BIO Doctoral Dissertation Improvement Grant (DDIG) (-$2.32 million) The BIO directorate's DDIG program supported awards in selected areas of the biological sciences. These grants provide partial support of doctoral dissertation research for improvement beyond the already existing project. The grants cover costs for doctoral candidates to participate in scientific meetings, to conduct research in specialized facilities or field settings, and to expand an existing body of dissertation research. Following a process of internal review and discussion regarding available resources, both the Divisions of Environmental Biology and Integrative Organismal Systems will no longer accept DDIG proposals. This decision was necessary because of increasing workload and changes in division priorities. This change is consistent with decisions made by other divisions in BIO, which have not participated in the DDIG competition for more than a decade.

East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI) (-$960,000) The EAPSI program, established in 1990, provided support to introduce U.S. students to research in science and engineering in the East Asia-Pacific region and fostered student-initiated professional relationships to facilitate future collaboration. EAPSI will be terminated in FY 2019 because it will have met its stated objectives. Furthermore, beginning in FY 2015, OISE shifted emphasis from small-scale to larger-scale catalytic activities. OISE will continue to focus on funding projects that are larger-scale with greater impacts, and will adapt the best practices from the EAPSI program in future funding opportunities.

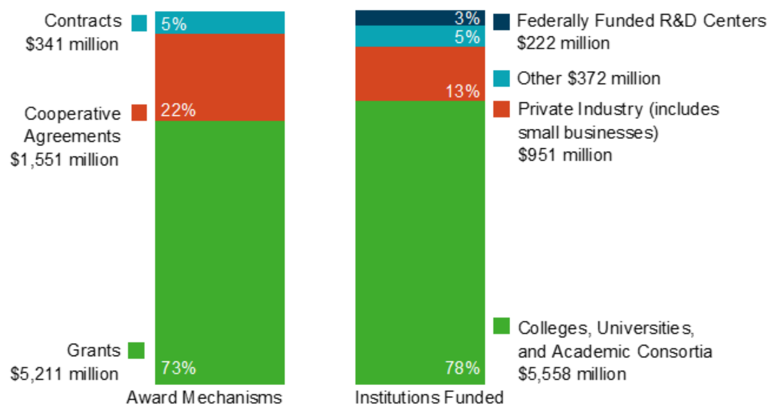
Information Technology Support Related to NSF Headquarters Relocation (-$2.50 million) This program achieved its stated goal in support of the NSF headquarters relocation support and stabilization in first quarter of FY 2018. Therefore, no additional funding is needed.

NSF by the Numbers

NSF by the Numbers: In FY 2019, NSF expects to evaluate approximately 50,600 proposals through a competitive merit review process and make approximately 11,100 new competitive awards, 8,400 of which will be new research grants and the remainder will be contracts and cooperative agreements. The number of new research grants decreases by roughly seven percent from previous levels, in keeping with the overall change in total NSF funding. This process involves approximately 250,000 proposal reviews, engaging on the order of 34,000 members of the science and engineering community participating as panelists and proposal reviewers. In a given year, NSF awards reach over 1,800 colleges, universities, and other public and private institutions in 50 states, the District of Columbia, and Puerto Rico. In FY 2019, NSF support is expected to reach approximately 354,850 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 2017, it is expected that the relative shares in FY 2019 will be similar. As shown on the graph, 95 percent of NSF's FY 2017 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, multi-user facilities.). Contracts are used to acquire products, services, and studies (e.g., program evaluations) required primarily for NSF or other government use.

NSF Award Mechanisms and Institutions Funded
FY 2017 Obligations for Research and Education Programs
($7,103 million)



Notes: NSF Research and Education Programs include—Research & Related Activities, Education & Human Resources, and Major Research Equipment & Facilities Construction appropriations.

Other institutions funded include federal, state, and local governments; nonprofit organizations; and international organizations.

R&D = Research and Development.

Totals may not add due to rounding.

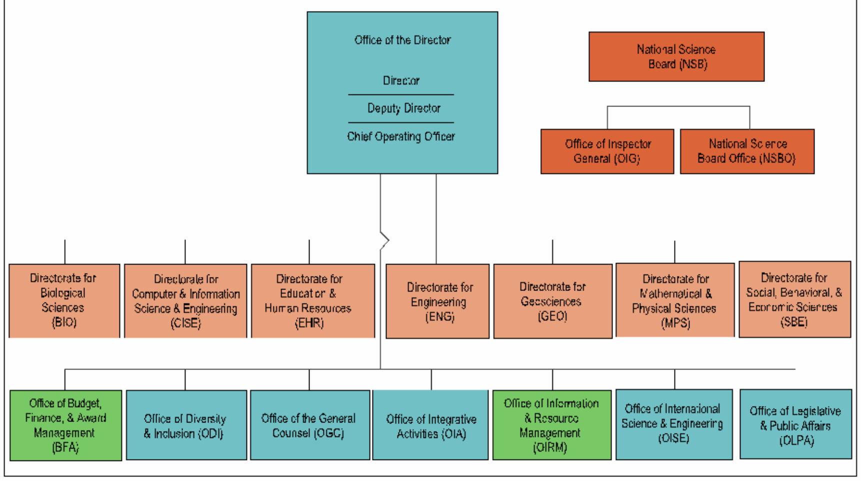
Most NSF awards are to academic institutions. As shown in the chart, 78 percent of support for research and education programs ($5,558 million) was to colleges (including two-year and community colleges), universities, and academic consortia. Private industry, including small businesses, accounted for 13 percent ($951 million), and support to Federally Funded Research and Development Centers (FFRDCs) accounted for three percent ($222 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 2017, FY 2018, and FY 2019. This indicator is useful in gauging the relative impact of different funding levels. In FY 2019, NSF expects to make approximately 11,100 new awards, which corresponds to a funding rate of about 22 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.

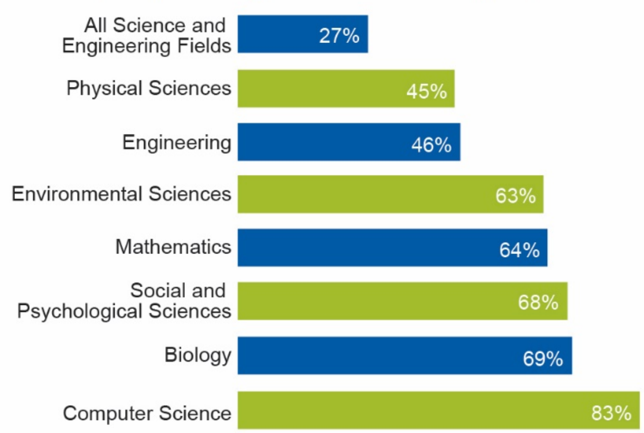
Figure 1.3
NSF FY 2017 Organization Chart



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

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



Notes: Biology includes Biological Sciences and Environmental Biology. Biology and Psychological Sciences exclude National Institutes of Health funding from the total amount of federal support.
Source: NSF/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FY 2015.

Highlights

For over 60 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.

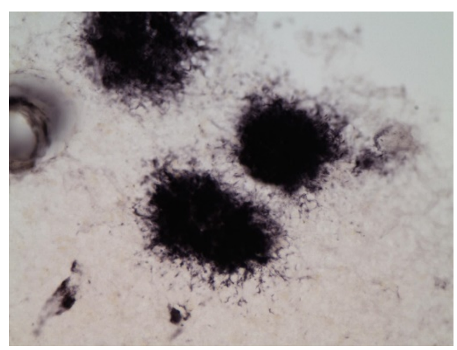
Ultrasensitive detector for physics and medicine

Novel magnetic sensors can speed diagnosis of heart, brain, and fetal conditions.
Credit: iStock.com/Pitju

NSF-funded research to discover fundamental particles and forces has led to a new tool with applications including brain research, diagnosis of abnormal heart rhythms, and pre-surgical imaging. Originally built to precisely measure very faint magnetic fields for basic physics experiments, the ultrasensitive detector, called an atomic spin magnetometer, has validated fundamental theories about the symmetry of space. Furthermore, the device's ability to sense magnetic fields 1,000 times weaker than those in the human brain made it a candidate for additional applications in medicine and neuroscience. Two startup companies, TwinLeaf Precision Sensors and QuSpin, are advancing the technology for commercial use.

New research detects Alzheimer’s disease markers in nonhuman primates

NSF-funded researchers discovered proteins associated with Alzheimer's disease–believed to be unique to humans–in a sample of brains of aged chimpanzees. It has been suggested that humans are uniquely susceptible to Alzheimer's, potentially because of genetic differences from other primates, changes to the human brain during evolution, and longer lifespans. Understanding these differences can provide key insights into identifying the causes of Alzheimer’s and working towards a cure. The identification in the aged chimpanzees of amyloid beta and tau lesions, hallmarks of Alzheimer's diagnosis, is a significant advancement in understanding the brain and Alzheimer's.



Amyloid beta plaques in the brain of a 58-year-old female chimpanzee.
Credit: Mary Ann Raghanti, Kent State University

Highlights

Quadriplegic ‘feels’ again thanks to brain-computer interface and robotic arm combination

From buttoning a shirt to grasping a cup, the ability to manipulate objects is aided by the sense of touch, which is why traditional prosthetics can only provide patients with very limited functions. Earlier this year, a quadriplegic man experienced the sense of touch again through a robotic arm connected to a brain-computer interface (BCI) implanted in his head that allowed him to “feel” pressure on the robotic hand. The blueprint for the BCI-robotic arm system came from NSF-funded basic research that examined the neural activity of monkeys as they manipulated objects. The advancement is paving the way for future touch-sensitive prosthetics.

A man manipulates a robotic arm via a computer chip in his brain.
Credit: University of Pittsburgh Medical Center/Pitt Health Sciences

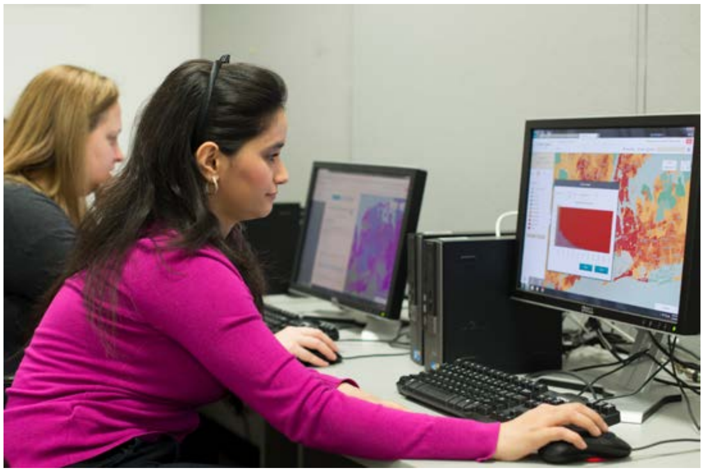
VLA reveals distant galaxy’s magnetic field

With the help of a gigantic cosmic lens, astronomers have measured the magnetic field of a galaxy nearly five billion light-years away. The achievement is giving them important new clues about a problem at the frontiers of cosmology—the nature and origin of the magnetic fields that play an important role in how galaxies develop over time. The scientists used NSF’s Karl G. Jansky Very Large Array (VLA) to study a star-forming galaxy that lies directly between a more-distant quasar and Earth. The galaxy’s gravity serves as a giant lens, splitting the quasar’s image into two separate images as seen from Earth. The radio waves coming from this quasar, nearly 8 billion light-years away, are preferentially aligned, or polarized. This discovery provides an important clue about how galactic magnetic fields are formed and evolve over time.

Artist’s conception of a gravitational lens arrangement that allowed astronomers to measure galaxy’s magnetic field.
Credit: Bill Saxton, NRAO/AUI/NSF; NASA, Hubble Heritage Team, STScI/AURA), ESA, S. Beckwith (STScI). Additional Processing: Robert Gendler

Highlights

Development of online visualization tool adopted by Census Bureau



Undergraduate sociology students use Social Explorer to visualize census data.
Credit: Aisha Hassan, Queens College, CUNY

The U.S. Census Bureau's Census Explorer is an online, interactive mapping tool that enables members of the media and public to visualize census data at the state, county and neighborhood levels. The web-based platform is built on a data visualization tool, called Social Explorer, developed by an NSF-funded researcher to help undergraduate sociology students studying demography better visualize U.S. census data. Census Explorer users can create maps on a range of data, including median household income and home ownership rate. Within the first few months of the tool's launch, more than 100,000 users had created four million data maps.

Eight ways the National Science Foundation supports our troops

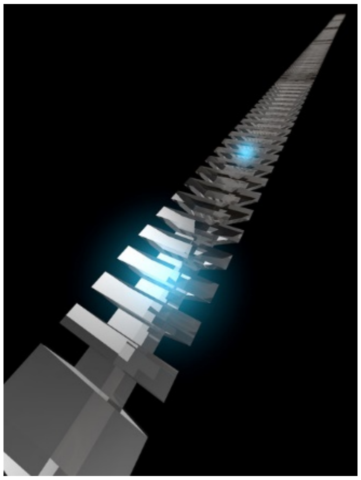
Since we were founded, securing the national defense has been a key part of the NSF mission. In recent years, we have lived up to that responsibility by funding research on building a stronger bulletproof vest, countering violent extremism, creating better GPS technology and improving prosthetics with brain-computer interface. Our support has also gone towards minimizing blood loss in battle wounds, helping military veterans with PTSD, detecting explosives and predicting conflict. NSF is proud of the role it plays in keeping American soldiers safe and military technology on the cutting-edge.

University of Maryland's brain cap technology. Alessandro Presacco, a graduate researcher in UMD's Neural Engineering and Smart Prosthetics Lab, adjusts a version of Brain Cap headset worn by Steve Graff, a bioengineering doctoral student. Looking on is lab director and Brain Cap creator José 'Pepe' Contreras-Vidal.
Credit: John Consoli, University of Maryland

Highlights

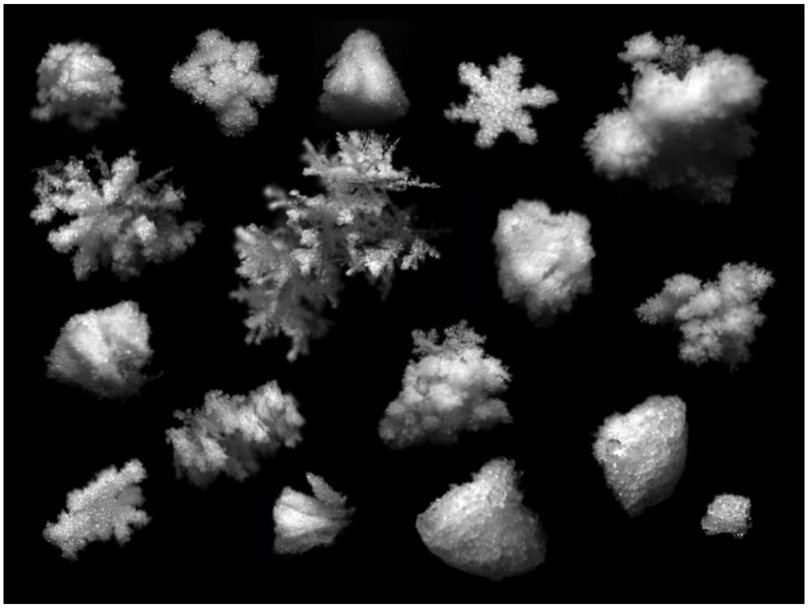
First on-chip nanoscale optical quantum memory developed

NSF-funded researchers have built the first nanoscale optical quantum memory device that could one day be used to create more reliable and secure internet communications. Quantum memory stores information in a similar fashion to the way traditional computer memory does, but on individual quantum particles—in this case, photons of light. This method takes advantage of the peculiar features of quantum mechanics to store data more efficiently and securely. The use of individual photons to store and transmit data has long been a goal of engineers and physicists because of the potential to carry information reliably and securely. Because photons lack charge and mass, they can be transmitted across a fiber optic network with minimal interactions with other particles.



Artist's rendition of Faraon's quantum memory device.
Credit: Ella Maru Studio

Safer winter driving with snowflake imaging



A high-speed, three-camera system reveals formation of an ice pellet.
Credit: Tim Garrett, University of Utah

Falling snow makes winter driving a challenge. Transportation planners, road crews and emergency managers can now estimate real-time accumulations with active imaging from multi-angle snowflake cameras (MASC). NSF-funded research led to the development of MASC, which images snowflakes down to the diameter of a human hair and simultaneously measures how fast they fall. These data have been critical for verifying snowfall predictions and winter precipitation algorithms for weather radars.