NSF FY 2020 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..."***

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.

<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.

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:

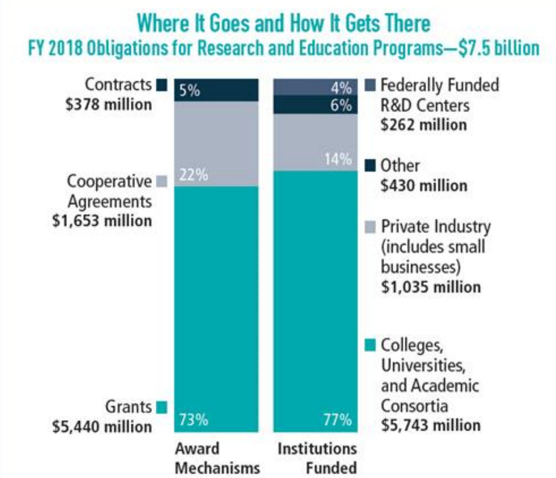
- **Ensure that Key Program Investments Are on Track:** Ensure that key FY 2020 NSF-wide program investments are implemented and on track.
- **Ensure that Infrastructure Investments Are on Track:** Ensure program integrity and responsible stewardship of major research facilities and infrastructure.
- **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.

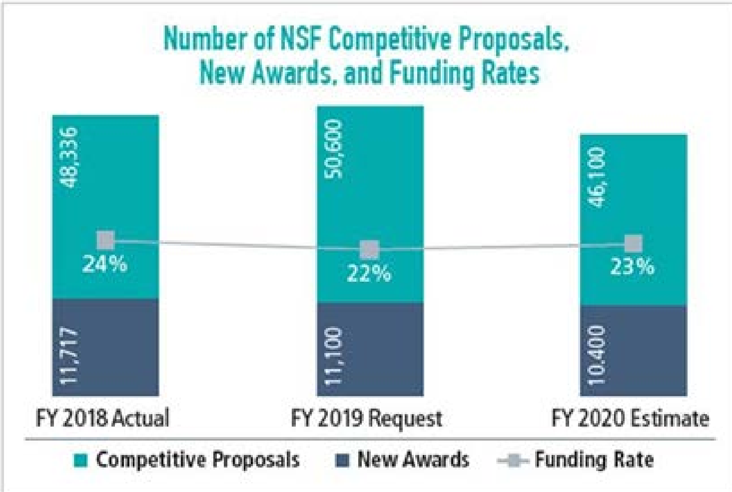


This chart shows the distribution of NSF's obligations by institution type and funding mechanism. While the data shown are based on FY 2018, the relative shares should provide a good indication of the FY 2020 distribution.

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.

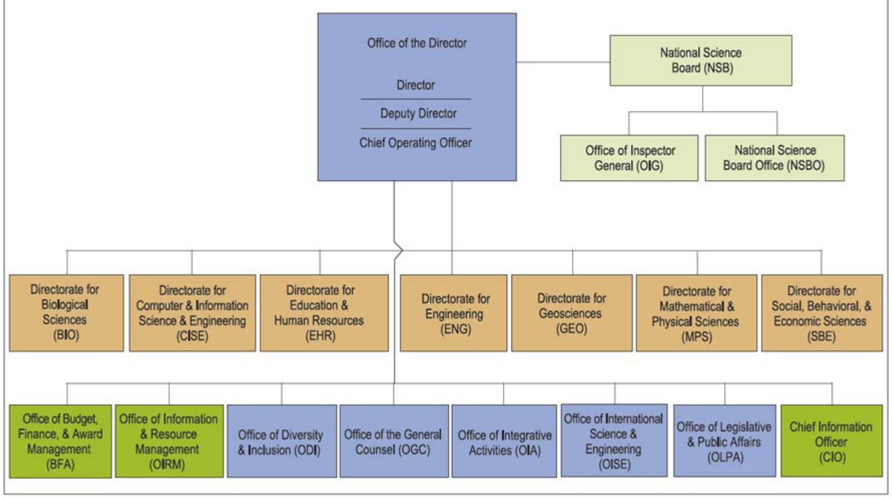


The chart on the left presents a high-level, agency-wide estimate of funding rates, or proposal "success," as a comparison of the number of competitive proposals, new awards, and funding rate between FY 2018, FY 2019, and FY 2020. In FY 2020, NSF expects to make approximately 10,400 new awards, which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

Organization and Role in the Federal Research Enterprise

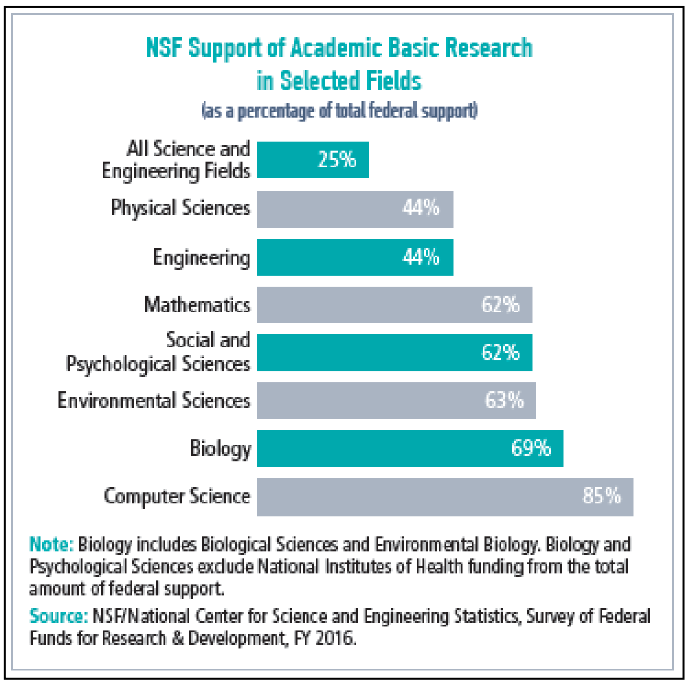
NSF's comprehensive and flexible support of meritorious projects enables the Foundation to identify and foster both fundamental and transformative discoveries and broader impacts within and among fields of inquiry. NSF has the latitude to support emerging fields, high-risk ideas, interdisciplinary collaborations, 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.

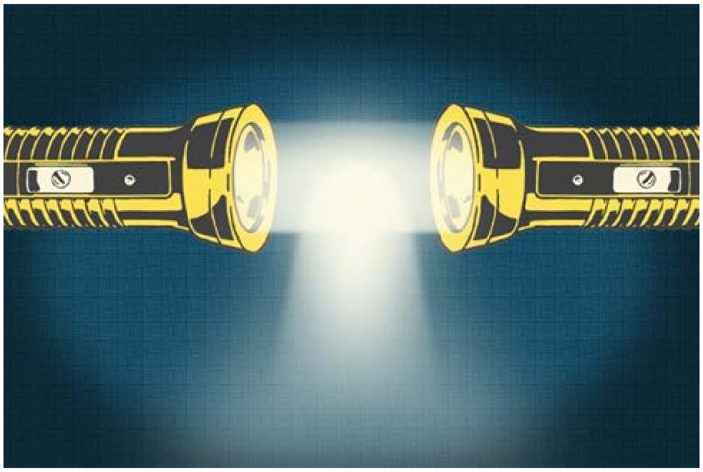
NSF's annual budget represents approximately 25 percent of the total federal budget for basic research conducted at U.S. colleges and universities, and this share increases to approximately 59 percent when medical research supported by the National Institutes of Health is excluded. In many science and engineering fields, NSF is the primary source of federal academic support.



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.