

NSF FY 2022 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...”

NSF is unique in carrying out its mission by supporting research across all fields of science, technology, engineering, and mathematics, and all levels of STEM education. NSF investments are critical to the economic and national security interests of the nation and development of a future-focused science and engineering workforce that draws on the talents of all Americans.

Last year, NSF celebrated its 70th anniversary. Over the past seven decades, NSF has funded research and researchers, innovations and innovators, and world-class infrastructure that have garnered incredible benefits to the nation. The Internet, Google, Qualcomm, 3D printing, the economic theory underpinning spectrum auctioning and kidney exchanges, and even the polymerase chain reaction (PCR) testing technique that has been critical in the fight against COVID-19 are all examples of the outcomes and benefits of NSF investments. Many of the technologies and industries that are the focus of national conversations around competitiveness today, including artificial intelligence, quantum information science, advanced manufacturing, advanced wireless, and biotechnology, to name a few, are rooted in sustained NSF support for research at the frontiers of science and engineering.

As NSF looks to the future, the agency’s capacity to continue to produce breakthroughs, to innovate, to identify the industries that we cannot even imagine today, to accelerate the translation of research results to practice, and to cultivate the diverse workforce needed to power our country forward, all must be strengthened at speed and scale. NSF has the know-how and energy to create a brighter future for our Nation and is guided by the Director’s vision expressed in three pillars that point to opportunities that we must seize:

1. Advancing the frontiers of research into the future
2. Ensuring accessibility and inclusivity
3. Securing global leadership in science and technology

These pillars support the Administration’s priorities for the FY 2022 request to Congress to enhance fundamental research and development, improve equity in science and engineering, advance climate science and sustainability research, continue construction of forefront research infrastructure. These priorities, expanded on below, dovetail precisely with the Director’s pillars and are addressed by NSF investments at all potential funding levels, appearing repeatedly in the broad portfolio of fundamental research that is the heart of NSF’s mission. They animate new and expanded efforts and they connect existing efforts throughout the portfolio of research programs.

Enhances Fundamental Research and Development

The FY 2022 request to Congress provides \$9.43 billion, an increase of \$1.55 billion above the FY 2021 enacted level, to support research across the spectrum of science, engineering and technology, including biological sciences; computer and information sciences; engineering; geosciences; math and physical sciences; social, behavioral, and economic sciences; and education. With this additional funding, NSF will continue to be the champion of basic and fundamental research and will strengthen it at speed and scale.

Strengthens U.S. Leadership in Emerging Technologies

We are currently facing a defining moment for the Nation. Global competition for leadership and talent in science, engineering and technology is at an all-time high, inspiring and motivating us to accelerate our progress to be in the vanguard of discovery and innovation. For the United States to remain a global leader, we must recommit to investing in breakthrough technologies and innovation, fostering partnerships, and nurturing talent, thereby encouraging the innovative spirit that has been the source of our leadership over the past seven decades.

On March 31, the Administration released the American Jobs Plan, which will create millions of good jobs, rebuild our country's infrastructure, and position the United States for the future. As part of that proposal, the Administration proposes investing \$50 billion over eight years in a new directorate for technology at NSF that will collaborate with and build on existing programs across the government. This directorate will closely collaborate with all of NSF's other directorates and offices, as well as with other stakeholders in the Nation's research, innovation, and education enterprise, to advance science and engineering research and innovation leading to breakthrough technologies as well as solutions to national and societal challenges, sustaining and enhancing U.S. competitiveness on a global stage; accelerate the translation of fundamental discoveries from lab to market, advancing the U.S. economy; and create education pathways for every American to pursue new, high-wage jobs, supporting a diverse workforce of researchers, practitioners, and entrepreneurs.

The creation of this new Directorate for Technology, Innovation, and Partnerships (TIP) will allow the agency to continue to support innovation across all disciplines of science and engineering, at the speed that is required in today's rapidly changing landscape.

Advances Equity in Science and Engineering

The FY 2022 Request to Congress seeks \$100 million, roughly a 50 percent increase, in funding for programs that aim to increase participation in science and engineering of individuals from racial and ethnic groups underrepresented in these fields. Funding will support curriculum design, research on successful recruitment and retention methods, development of outreach or mentorship programs, fellowships, and building science and engineering research and education capacity at HBCUs and other minority-serving institutions. Additionally, through the Established Program to Stimulate Competitive Research (EPSCoR), funded separately, NSF looks to enhance research competitiveness of targeted jurisdictions (states, territories, commonwealth) by strengthening STEM capacity and capability. These STEM-related opportunities are building capacity and infrastructure across the nation, seeding and nurturing innovation clusters with stronger economic outcomes and good quality jobs.

NSF is investing in education research across all levels of learning—from preK-12 through graduate education and beyond—which then informs education and training programs to better develop skill sets in cutting-edge technologies, promote highly collaborative team science, and foster greater diversity in the workforce. NSF will continue to invest robustly across its suite of broadening participation programs. In doing so, NSF will work tirelessly to ensure that there are no barriers to equal opportunity at NSF or in the delivery of its programs. These investments will be central to our ability to achieve those goals.

Advances Climate Science and Sustainability Research

The FY 2022 Request to Congress provides \$1.20 billion for climate and clean energy-related research. NSF will fund a broad portfolio of research related to climate science and clean energy, including research on atmospheric composition, water and carbon cycles, computational modeling of climate systems, renewable energy technologies, materials sciences, and social, behavioral, and economic research on human responses to climate change.

NSF's investments in basic research, including funding and efforts supported in the Administration's

FY 2022 discretionary request, impact nearly every aspect of America’s clean energy future—from fundamental physics, chemistry, and materials science to data and computation including artificial intelligence, to large-scale systems engineering and cyber-infrastructure. NSF’s clean energy investments support innovative interdisciplinary basic and translational research and education that may broadly contribute to future sustainability, such as the conversion, storage, and distribution of diverse power and fuel sources (including smart grids); the science and engineering of energy materials, energy use, and energy efficiency; and the ways that people think about and use energy.

Continues Construction of Forefront Research Infrastructure

Research infrastructure funded by NSF provides the cutting-edge tools needed to advance fundamental research and development and both contribute to, and benefit from, emerging technology. The Administration’s discretionary request invests in the continued construction of major NSF research facilities, including long-term upgrades of NSF’s major Antarctic infrastructure and upgrades to the Large Hadron Collider. It also supports construction of the Vera C. Rubin Observatory to enable astronomy research. In addition, the discretionary request seeks funding for the construction and procurement of mid-scale and smaller research facilities and equipment at colleges, universities, and other research institutions across the nation.

The FY 2022 President’s Budget Requests \$10.17 billion for NSF, an increase of 20 percent from the current budget. NSF stands ready to maximize the impact of this increase in funding and tackle critical challenges to bolster the U.S. economy and our leadership in critical and emerging areas of research and technological advancements.

FY 2022 ORGANIZING PRINCIPLES

The three pillars of the NSF Director's vision for the future of the agency support the Administration's priorities and give shape to the organizing principles for the Fiscal Year 2022 discretionary request. Examples of specific investments in each pillar follow.

1. Advancing the Frontiers of Science and Engineering

The first pillar, advancing the frontiers of science and engineering research into the future has been the heart of NSF's mission for over seven decades and will be further strengthened in the years to come. By seeding strategic investments, NSF steers the frontiers of discovery and innovation toward breakthroughs that put the United States at the forefront of global leadership in science and technology.

Since its inception, NSF has been the foundation for new industries. NSF funds the high-risk, high-reward research that has the potential to bring the world new discoveries. Each year, thousands of researchers expand the base of human knowledge and, in doing so, unlock new possibilities. They have built autonomous vehicles; revolutionized our wireless networks; developed life-saving medical technologies; transformed manufacturing; and brought digital tools to agriculture. Curiosity-driven, exploratory research is a critical component to the nation's current and future success. NSF's continued investment in these new and emerging technologies will result in the creation of new, high-wage, good-quality jobs.

The President's Fiscal Year 2022 discretionary request advances the frontiers of research into the future by making critical investments in new industries.

- **Advanced Manufacturing** (\$418.51 million) research supported by NSF accelerates advances in manufacturing with emphasis on multidisciplinary research that fundamentally alters and transforms manufacturing capabilities, methods, and practices. NSF investments will make producing next-generation products and services more efficient and sustainable and will lead to advantages such as less time-to-market, new performance attributes, cost savings, energy savings, and reduced environmental impacts. In FY 2022, these investments will support advanced manufacturing research, future manufacturing research, workforce development, and transition to practice. NSF invests in advanced manufacturing to increase future U.S. prosperity, as well as the Nation's competitiveness, security, and quality of life.
- **Advanced Wireless** (\$166.61 million) will provide the backbone that connects users, devices, applications, and services that will continue to enrich America's economy. NSF's leadership in advanced wireless research has three inter-related components starting with supporting fundamental research on advanced wireless. In FY 2022, NSF, in partnership with other federal agencies and the private sector, will support the Resilient and Intelligent Next-Generation Systems (RINGS) program, laying the groundwork for next-generation wireless connections that will enable faster service, networks more resilient to natural disasters and service interruptions, and broader access for people across the U.S. NSF will also continue to support the Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT) program and research in artificial intelligence and machine learning techniques that address the diverse, stringent quality-of-service requirements of future wireless applications. The second component supports advanced wireless research testing platforms. Funding in this Request will be dedicated to pursuing a convergent approach to validate advanced wireless research through its PAWR program. The PAWR testbeds will support proofs of concept for dynamic spectrum sharing across diverse geographic and spectrum use cases. The third component is dedicated to developing a diverse workforce trained in advanced wireless technologies.
- **Artificial Intelligence** (\$734.41 million) is advancing rapidly and holds the potential to vastly transform our lives. NSF-funded research is now laying the seeds for advances in AI that will transform

not just these areas, but essentially every area of human endeavor, including science, education, energy, manufacturing, and agriculture. NSF's ability to bring together numerous fields of scientific inquiry uniquely positions the agency to lead the Nation in expanding the frontiers of AI. In FY 2022, NSF will increase support for foundational research in AI, including machine learning and deep learning, natural language technologies, knowledge representation and reasoning, robotics, and computer vision, along with the fairness, accountability, transparency, explainability, safety, security, and robustness across all areas of AI. NSF will also support use-inspired research, education and workforce development, and access to data and advanced computing research infrastructure that collectively enhance AI. In FY 2022, NSF will continue support (\$69.11 million) for the National AI Research Institutes program. In addition, NSF will emphasize AI research, education and workforce development, and infrastructure activities at minority-serving institutions (MSIs). Specifically, NSF will broaden participation by intentionally focusing on the development of AI research capacity at MSIs, the involvement of populations long underrepresented in AI in research activities, and the formation of partnerships spanning multiple MSIs as well as MSIs and other institution types.

- **Biotechnology** (\$382.26 million) comprises the data, tools, research infrastructure, workforce capacity, and innovation that enable the discovery, utilization, and alteration of living organisms, their constituent components, and their biologically related processes. NSF's investment will include research and infrastructure in genomics, proteomics, synthetic biology, chemical biology, bioinformatics, computational biology, data analytics, structural biology, biophysics, tissue engineering, and development of new types of biomaterials, bio-probes, bio-based microelectronics, and biomanufacturing. In addition, NSF invests in educational programs that ensure a trained workforce to support U.S. capabilities in biotechnology, together with research on the ethical, legal, economic, and environmental consequences of synthetic biology and other biotechnologies, contributing to public understanding of product adoption and socially responsible use.
- **Quantum Information Science (QIS)** (\$260.0 million) research will advance fundamental understanding of uniquely quantum phenomena that can be harnessed to promote information processing, transmission, and measurement in ways that classical approaches do less efficiently, or not at all. Building upon more than three decades of exploratory discovery, NSF investment in QIS will help propel the Nation forward as a leading developer of quantum technology. These investments are a key component of the National Quantum Initiative (NQI) and address the Administration's focus on helping build new industries. NSF's QIS investments build upon the agency's longstanding and continuing foundational investments in QIS as well as more recent, interdisciplinary investments in centers and small teams and targeted workforce development efforts. Investments will target all major areas of quantum computing, communications, sensing, networking, and simulation. NSF will continue the investment in Research Experiences for Undergraduates (REU) and NSF Research Traineeship (NRT) awards related to QIS begun in FY 2021 and will add intentional activities designed to grow the participation of investigators and students from institutions currently underrepresented in QIS.

Climate Change Activities

NSF has been investing for several decades in climate and global change issues through a portfolio of programs that advance the frontiers of knowledge, provide state-of-the-art instrumentation and facilities, develop new analytical methods, and enable cross-disciplinary collaborations while also cultivating a diverse, highly-trained workforce and developing educational resources. NSF's climate and global change-related programs support the research and related activities to advance fundamental understanding of physical, chemical, biological, and human systems and the interactions among them. NSF is positioned to continue this important work in supporting climate science and sustainability research.

- **U.S. Global Change Research Program (USGCRP)** (\$762.0 million) continues to support research that contributes to the USGCRP goal areas to (1) advance scientific knowledge of the integrated natural and human components of the Earth system and (2) inform decisions by providing the scientific basis

to inform and enable timely decisions on adaptation and mitigation. In FY 2022, NSF will continue to engage with other USGCRP agencies on priorities from intra-seasonal to centennial predictability, predictions, and projections; water cycle research; impacts of climate change on the nation's critical ecosystems, including coastal, freshwater, agricultural and forests systems; understanding the impacts of global change on the Arctic region and effects on global climate; and fundamental research on actionable science. In addition, NSF will further seek greater integration of social-science research, methodologies, and insights into understanding and supporting responses to global change, improving computing capacity, and maintaining needed observational capabilities over time.

- **Clean Energy Technology (CET)** (\$440.0 million) and NSF's clean-energy investments in high-risk, high-reward ideas from researchers across the science and engineering spectrum create broad new understanding and innovations that may increase energy efficiency, enhance sustainability, mitigate climate change, or lead to other societal benefits. NSF's investments in integrated clean energy research and education span longstanding programs as well as focused new solicitations and will continue to advance the fundamental science and engineering underlying clean energy technologies and infrastructure. NSF also will support multidisciplinary research in areas such as affordable green housing and sustainable systems for clean water, clean transit, and other infrastructure. Added NSF investments will help build a diverse future clean-energy workforce and advance the translation and deployment of innovative technologies. In FY 2022, NSF will focus on investing in fundamental clean-energy research, research infrastructure enabling sustainable energy generation and distribution and allowing for the creation of more energy-efficient energy systems, the clean energy workforce, and the translation of fundamental discoveries in clean energy into technologies and systems.

NSF Innovation Corps (I-Corps™) (\$40.0 million) connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, fostering a national innovation ecosystem that links scientific discovery with technology development, societal needs, and economic opportunities. In FY 2022, NSF expects to fund 250-300 teams, partnering with other federal agencies and programs, states, and regional organizations as well as a set of new I-Corps™ Hubs. I-Corps™ Teams are funded at \$50,000 per Team with a duration of six months. I-Corps™ Hubs are supported for up to five years, at up to \$3.0 million per Hub per year.

Secure and Trustworthy Cyberspace (SaTC) (\$153.0 million) is a multi-year investment, aiming to develop an organized scientific body of knowledge that informs the theory and practice of cybersecurity and privacy, and an improved understanding of the causes of and mitigations for current threats. Through SaTC, NSF funds a broad and deep multidisciplinary research and education portfolio spanning cybersecurity and privacy, whose results underlie methods for securing critical infrastructure. Further, NSF expects to produce an innovation ecosystem that ensures (a) new and existing technologies are secure from both current threats and potential future threats as technologies evolve, and (b) users' information is protected from violations of privacy despite new attack surfaces that these technologies may present. FY 2022 investments will support foundational research in this space, accelerate transition to practice, and enhance education and preparation of cybersecurity researchers and professionals.

2. Ensuring Accessibility and Inclusivity

The second pillar, ensuring accessibility and inclusivity in STEM fields is increasingly important. There is tremendous untapped STEM potential throughout the nation. To meet the needs of the future workforce, every person needs access to a quality STEM education. Every demographic and socioeconomic group in every geographic region of the country is full of talent that must be inspired and motivated to participate in STEM and contribute to the research and innovation enterprise. We must scale up existing pathways into STEM fields and create new tracks into science and engineering.

NSF's commitment to finding talent provides opportunities that build strong STEM pathways which leads to a well-paid workforce and a vibrant U.S. economy. To that end, the following programs are funded in the FY 2022 Budget Request to Congress.

- **ADVANCE** (\$20.50 million) seeks to increase the representation and advancement of women in academic science and engineering careers. This program encourages institutions of higher education and the broader STEM community to address aspects of STEM academic culture and institutional structure that may differentially affect women faculty and academic administrators.
- **Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)** (\$46.50 million) is committed to enhancing the quality of undergraduate STEM education and research at HBCUs to broaden participation in the Nation's STEM workforce. HBCU-UP provides awards to develop, implement, and study evidence-based innovative models and approaches for improving the success of HBCU undergraduates so that they may pursue STEM graduate programs and/or careers.
- **Historically Black Colleges and Universities Excellence in Research (HBCU-EiR)** (\$33.96 million) program supports projects that enable STEM and STEM education faculty to further develop research capacity at HBCUs and to conduct research.
- The **Hispanic-Serving Institutions Program (HSI)** (\$56.50 million) seeks to enhance the quality of undergraduate STEM education at HSIs and to increase retention and graduation rates of undergraduate students pursuing degrees in STEM fields at HSIs. The HSI program seeks to build capacity at HSIs that typically do not receive high levels of NSF grant funding.
- The **Louis Stokes Alliances for Minority Participation (LSAMP)** (\$69.50 million) is an alliance-based program that works to increase the number of STEM baccalaureate and graduate degrees awarded to populations historically underrepresented in STEM disciplines.
- The **Tribal Colleges and Universities Program (TCUP)** (\$21.0 million) provides awards to Tribal Colleges and Universities, Alaska Native-serving institutions, and Native Hawaiian-serving institutions to promote high quality STEM education, research, and outreach.
- **Established Program to Stimulate Competitive Research (EPSCoR)** (\$239.64 million) seeks to advance excellence in science and engineering research and education, enhancing the competitiveness of EPSCoR jurisdictions in the disciplinary domains supported by NSF.
- **Build and Broaden (B2)** (\$8.0 million) supports research collaborations between scholars at minority-serving institutions (MSIs) and scholars in other institutions or organizations. B2 is designed to support research projects that builds capacity and enhance research productivity in the SBE sciences at MSIs; provides researchers with new ways to diversify and sustain collaborations; fosters partnerships that strengthen career and research trajectories for faculty at MSIs; and contributes to stronger, more innovative science by diversifying research and widening the STEM pipeline.
- **CISE Minority-Serving Institutions Research Expansion (CISE-MSI) program** (\$7.0 million) enhances the capacity at MSIs for computing research, increasing the number of research projects from MSIs funded by CISE and broadening the participation of MSIs in CISE programs.

3. *Securing Global Leadership*

The third pillar is securing global leadership in science and technology. America must lead by our actions and our values. Key tenets of this leadership are transparency, reciprocity and research integrity. NSF will work with like-minded partners who share these values and commitment to advancing scientific progress and prosperity. We will take the necessary steps to safeguard taxpayer investments and to ensure everyone is playing by the same set of rules.

NSF enhances American economic strength and security through partnering with foreign counterparts to promote international collaboration based upon the principles of honesty, openness, transparency, and reciprocal collaboration. Today, our enterprise is put at risk when other governments endeavor to benefit from the global research ecosystem without upholding these principles. Faced with such a risk, securing global leadership is now more important than ever. In March 2020, NSF created a new position of Chief of Research Security Strategy and Policy (CRSSP) as part of its continuing effort to ensure the security of federally funded research while maintaining open international collaborations. In FY 2021, NSF is continuing to refine the CRSSP team efforts and contractor support service capabilities.

As part of the President's Fiscal Year 2022 discretionary request, NSF will build its analytic capabilities to proactively identify conflicts of commitment, vulnerabilities of pre-publication research, and risks to the merit review system. Additionally, NSF will develop external training for the research community to ensure NSF is clearly communicating the benefits of international collaborations as well as the risks from improper foreign government interference.

Partnerships

While not an individual pillar, the partnerships NSF cultivates are interwoven through and between each of the pillars. NSF has a rich history of not only pursuing direct partnerships with other agencies, private industry and philanthropy, and like-minded countries, but also fostering environments where partnerships thrive, because they are powerful ways to leverage resources and deliver results.

RESEARCH INFRASTRUCTURE AND INSTRUMENTATION

The Nation's science and engineering activities rely on instrumentation that is geographically and technically accessible, cost effective, and managed well. To meet the infrastructure needs of the entire community, NSF is dedicated to supporting activities that ensure that instrumentation and infrastructure can be designed, developed, acquired, or constructed across the Nation, through programs with focused oversight and investments.

The **Major Research Instrumentation (MRI)** program is responsible for catalyzing new knowledge and discoveries by helping STEM professionals acquire or develop the instrumentation needed at their institutions. MRI grants support instrumentation in all NSF-supported research disciplines. MRI makes awards of up to \$4 million, for projects with total costs (including matching funding) as high as \$6.0 million.

In the American Innovation and Competitiveness Act (AICA) enacted in 2017, Congress directed the agency to develop a strategy for supporting research infrastructure with a total project cost above the upper limit for the MRI program and below the **Major Research Equipment and Facilities Construction (MREFC)** threshold. NSF responded by introducing the **Mid-scale Research Infrastructure (Mid-scale RI)** program as one of NSF's Big Ideas. This dedicated funding line implements a high-priority, agency-wide mechanism that includes upgrades to major facilities as well as stand-alone projects.

The goals of the Mid-Scale RI program are to:

- Provide access to cutting-edge mid-scale research infrastructure, including instrumentation.
- Enable agile development and implementation of frontier scientific and engineering research infrastructure with a high potential to significantly advance the Nation's research capabilities.
- Train early-career scientists and engineers in the development and use of advanced research infrastructure.

In FY 2022, NSF will invest a total of \$126.25 million in Mid-scale RI, split between two separate tracks, Mid-scale RI-1 (\$50.0 million), funded through R&RA, and Mid-scale RI-2 (\$76.25 million), funded through MREFC. Both use a biennial funding opportunity; the second solicitations for Mid-scale RI-1 (NSF-21-5055) and Mid-scale RI-2 (NSF-21-5376) were issued in FY 2021. Subject to availability of funding in FY 2022, Mid-scale RI-1 will support projects from its FY 2021 competition.

NSF Responsiveness to COVID-19 Impacts on Operating Facilities

The primary known impact of COVID-19 on operating facilities at the present time is the loss of science caused by a number of facilities having to suspend or reduce operations due to the pandemic; this loss of science does not generally result in NSF costs beyond the appropriated dollars except in a few cases. Additional NSF costs are being incurred for the Academic Research Fleet due to the reduction in reimbursable science missions, and by Antarctic Facility Operations because of the extensive quarantine and transportation procedures required to assure that COVID-19 is not carried to the U.S. Antarctic facilities.

Major Research Equipment and Facilities Construction

Construction projects that require an investment of more than \$100 million are supported in NSF's MREFC account. The FY 2022 Budget Request includes funding for four construction projects—the Antarctic Infrastructure Recapitalization program (formerly Antarctic Infrastructure Modernization for Science or AIMS), the two detector upgrades to operate at the High Luminosity-Large Hadron Collider (HL-LHC), the Vera C. Rubin Observatory, and the Regional Class Research Vessels (RCRV)—as well as Mid-scale RI-2, covering projects in the \$20 million to \$100 million range.

MREFC Account Funding, by Project

(Dollars in Millions)

| | FY 2020 Actual | FY 2021 Estimate ¹ | FY 2022 Request |
|---|-------------------|----------------------------------|--------------------|
| Antarctic Infrastructure Recapitalization | \$48.78 | \$90.00 | \$90.00 |
| HL-LHC Upgrade | 33.00 | 33.00 | 36.00 |
| Mid-scale Research Infrastructure | - | 76.25 | 76.25 |
| NEON | 0.74 | - | - |
| RCRV | 25.00 | - | 5.00 |
| Vera C. Rubin Observatory | 46.35 | 40.75 | 40.75 |
| Dedicated Construction Oversight | 0.97 | 1.00 | 1.00 |
| Total | \$154.84 | \$241.00 | \$249.00 |

¹ A total of \$129.35 million was carried forward from FY 2020 into FY 2021: \$29.71 million for AIMS, \$9.40 million for DKIST, \$65.0 million for Mid-scale RI, \$10.97 million for RCRV, \$10.07 million for the Rubin Observatory, and \$780,000 for Dedicated Construction Oversight.

The COVID-19 pandemic constitutes an unforeseen event that was not within the control of the recipients managing the ongoing major facility construction projects. NSF has policies for responding to these unforeseen events that were established in advance of the COVID-19 pandemic, which subsequently have been further refined to support the current situation. As appropriate, re-baselining of several projects will take place during FY 2021, as the cost and schedule impacts of COVID-19 become better known for FY 2022 and beyond.

NSF manages all U.S. Antarctic activities as a single, integrated program, making Antarctic research possible for scientists supported by NSF and other U.S. agencies. Impacts of the COVID-19 pandemic on U.S. Antarctic Program (USAP) operations required construction activities at McMurdo Station to be suspended and caused a significant delay to overall AIMS completion. In the meantime, other investments in facilities and infrastructure on the continent have emerged as priorities that cannot be deferred until after completion of AIMS. As a result the **Antarctic Infrastructure Recapitalization (AIR)** program was conceived as a rescoping of the Antarctic Infrastructure Modernization for Science (AIMS) project. AIMS construction will continue with a focus on meeting near-term needs, and unfunded parts of AIMS will be incorporated into the longer-term AIR program. FY 2022 funding for AIR (\$90.0 million) will be used to fund adjusted AIMS scope, if necessary, and transition to a broader recapitalization of NSF's Antarctic infrastructure.

The Large Hadron Collider is the world's largest and highest energy particle accelerator. Located near Geneva, Switzerland and operated by the European Organization for Nuclear Research (CERN), 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 2022, funding for **HL-LHC Upgrade** (\$36.0 million) will support year three of the five-year project that began in FY 2020, prior to the onset of the COVID-19 impact. Pandemic impacts are likely to result in future, and not yet quantified, changes to upgrade plans. This investment will upgrade components of the ATLAS and CMS detectors, enabling them to function at much higher collision rates following an upgrade to the LHC to increase its luminosity.

The **Regional Class Research Vessels** (\$5.0 million) are being designed to meet the needs of researchers for work in coastal zones in support of biological, chemical, physical, and geological oceanography. The

vessels will be capable of precise station-keeping for water column and sediment sampling, as well as supporting the use of remotely operated and autonomous vehicles. They will also enable virtual participation of shore-based scientists using telepresence/data presence technology, greatly expanding the potential user base. RCRV is the NSF-supported contribution to right-sizing and modernization of the U.S. Academic Research Fleet.

Vera C. Rubin Observatory (\$40.75 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 2022 will be the ninth year of a funding profile originally scheduled for nine years, and now likely to extend into a tenth year.

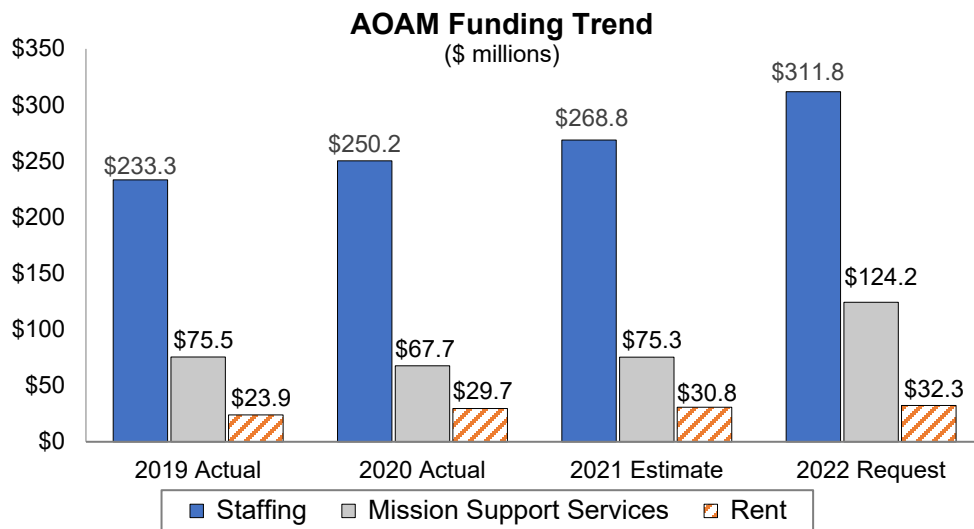
AGENCY OPERATIONS AND AWARD MANAGEMENT

In FY 2022, funding provides a total of \$468.30 million, an increase of \$93.37 million or 24.9 percent above the FY 2021 Estimate for the Agency Operations and Award Management (AOAM) account. NSF continues to operate as a lean agency with AOAM costs representing about 5 percent of NSF total FY 2022 budget.

The \$9.43 billion in research funding that NSF will support in FY 2022 is managed by the staff at NSF who enable research and steward the taxpayer investment. Investments in the AOAM account provide the fundamental framework through which the Foundation’s science and engineering research and education programs are administered. AOAM funds the essential services NSF needs to operate, and investments in the AOAM account continue to be an NSF priority.

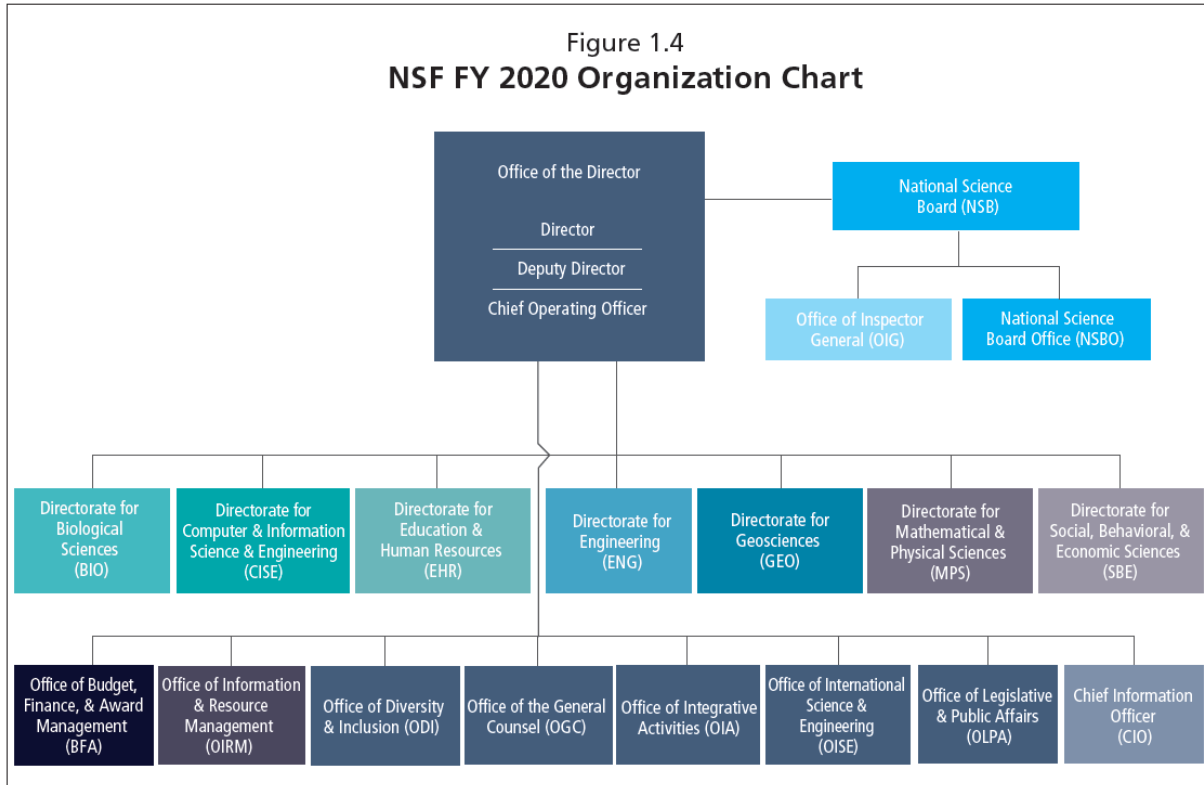
The AOAM account is largely the cost of NSF personnel and NSF’s headquarters location in Alexandria, VA. In the last several fiscal year budget requests, NSF reduced or held flat mission support services costs to accommodate the year-over-year increases in the fixed costs for staffing and rent. NSF then exercised its transfer authority to restore funding for those reduced activities.

The large increase in AOAM costs in FY 2022 is a course correction aimed at requesting the amount NSF estimates it needs and decreasing the reliance on the transfer authority to cover the full cost of doing business. The requested level also will enable NSF to establish a new directorate as described above, and to grow agency administration and operations, including additional staffing needs, with speed and scale to meet the needs of a \$10 billion federal research agency effectively and efficiently. Further, NSF anticipates continuing to move toward a hybrid work environment and the Request therefore includes resources for the necessary additional information technology and training for staff and supervisors to achieve this approach. In addition, NSF requests increases to provide for strategic human capital management, changes at the NSF headquarters building to respond to COVID-19 impacts, establishing a new effort for Science and Security including a Sensitive Compartmentalized Information Facility (SCIF) at the NSF headquarters building, and NSF-wide implementation of the Program Management Improvement Accountability Act (PMIAA) and other efforts to implement the policy requirements mandated by law, such as the American Innovation and Competitiveness Act (AICA), Digital Accountability and Transparency Act of 2014 (DATA Act), and Foundations for Evidence-Based Policymaking Act of 2018 (Evidence Act).



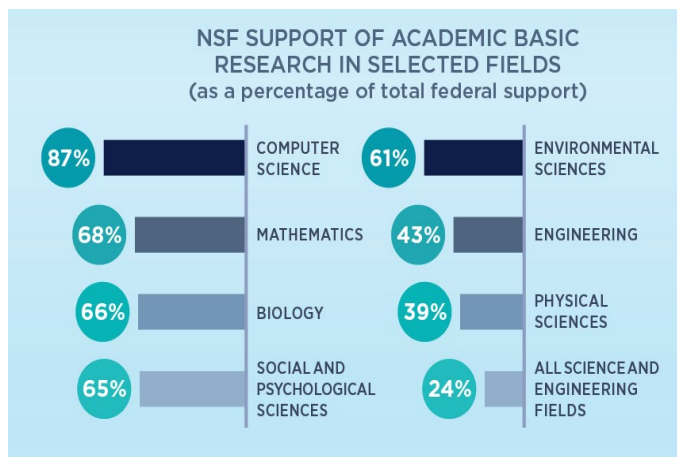
ORGANIZATION AND ROLE IN THE FEDERAL RESEARCH ENTERPRISE

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



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

NSF’s annual budget represents approximately 24 percent of the total federal budget for basic research conducted at U.S. colleges and universities. In many science and engineering fields, NSF is the primary source of federal academic support.

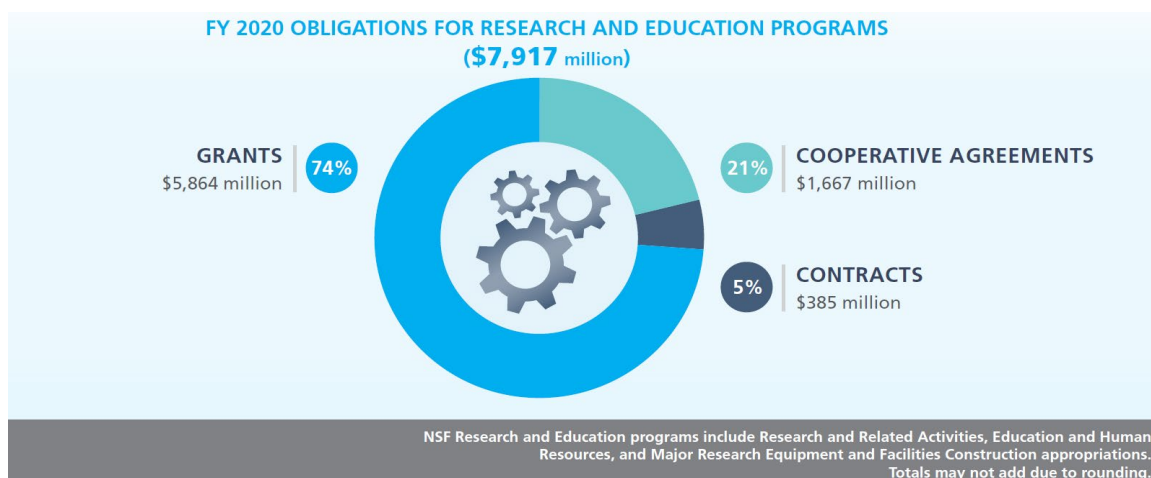


Note: Biology includes Biological Science and Environmental Biology. Biology and Psychological Sciences exclude National Institutes of Health funding from the total amount of federal support. *Credit: NSF/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FY 2018.*

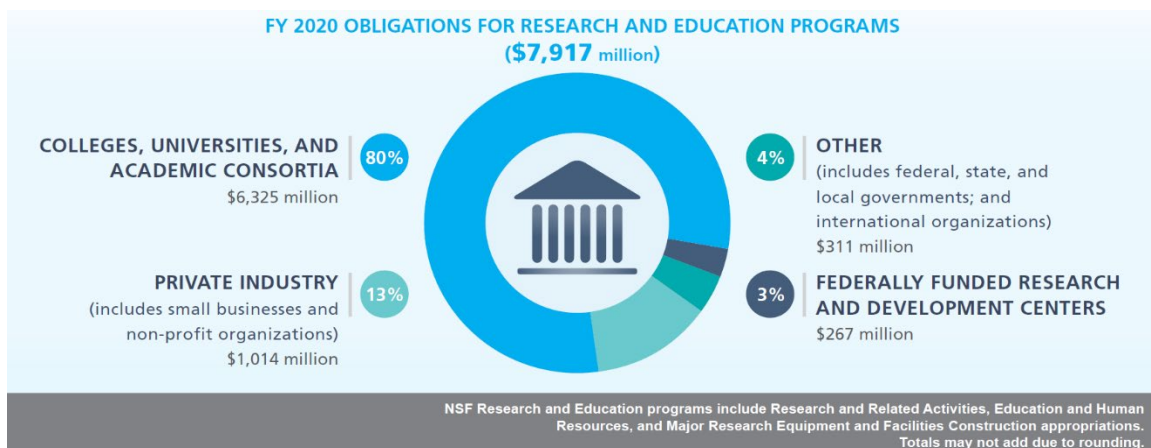
NSF BY THE NUMBERS

In FY 2022, NSF expects to evaluate approximately 47,900 proposals through a competitive merit review process and make approximately 13,800 new competitive awards, 11,500 of which will be new research grants and the remainder of which will be contracts and cooperative agreements.

The following two charts show the distribution of NSF’s obligations by funding mechanism and institution type. While the data are based on FY 2020, it is expected that the relative shares in FY 2022 will be similar. As shown below, 95 percent of NSF’s FY 2020 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 required primarily for NSF or other government use.



Most NSF awards are to academic institutions with 80 percent of support for research and education programs (\$6,325 million) being awarded to 822 different colleges, universities, and academic consortia. Private industry, including small businesses and non-profit organizations, accounted for 13 percent (\$1,014 million), and support to Federally Funded Research and Development Centers accounted for 3 percent, or \$267 million. Other recipients (federal, state, and local governments; and international organizations) received 4 percent (\$311 million) of support for research and education programs.



NSF continuously monitors key portfolio, proposal workload, and financial measures to understand short- and long-term trends and to help inform management decisions. The chart below 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 2016 and FY 2020. In FY 2020, there were increases in all three key measures.

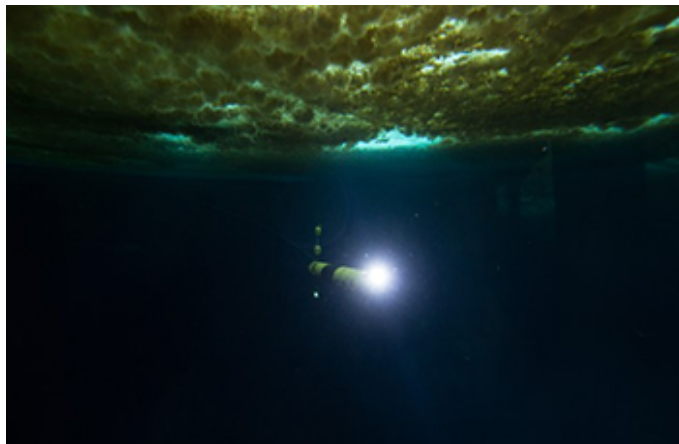


HIGHLIGHTS

For over 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.

Robotic underwater vehicle snaps first images of seafloor beneath Antarctica's Thwaites Glacier

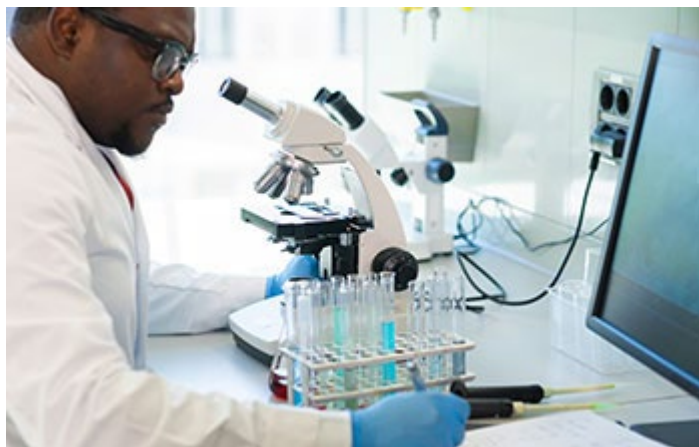
Antarctica is one of the most extreme environments on the planet. Despite the harsh environment and forbidding conditions, researchers funded by NSF are probing Antarctica's secrets above and below the ice. Using an underwater robot called Icefin, researchers with the International Thwaites Glacier Collaboration were able to study the ocean floor beneath the Thwaites Glacier—a fast-moving glacier about the size of Florida flowing into the Pine Island Bay off of West Antarctica. By diving beneath the waves, researchers are hoping to better understand the conditions in the area around the glacier and the changes taking place as it flows into the sea. The information is critical to our understanding of oceanography, sea-levels, and polar phenomena.



Scientists conduct first study beneath Antarctica's Thwaites Glacier.
Credit: Georgia Tech University.

Broadening Participation Research Center: HBCU STEM Undergraduate Success Research Center

Historically Black Colleges and Universities have a high success rate of graduating their students. NSF is awarding \$9 million to establish the center, led by researchers from Morehouse College, Spelman College and Virginia State University. Researchers will study the successful broadening participation practices of 50 HBCUs and develop evidence-based interventions with the aim of transforming mainstream education. The researchers will employ a convergent approach to education and share data to improve student outcomes across the HBCU network and other institutions. "Investing in the institutional capacity of HBCUs and developing diverse STEM talent is part of NSF's longstanding commitment to broaden participation of groups traditionally underrepresented in STEM," said NSF program officer, Claudia Rankins, who manages the HBCU program.



NSF Established New Center to Study Successful Undergraduate STEM Education Practices at Historically Black Colleges and Universities.
Credit: Maksim Shmeljov/Shutterstock.

AI in the classroom

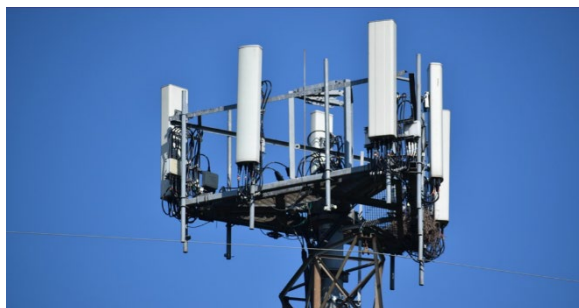
Enhancing educational outcomes for all students is a critical part of building a STEM-enabled workforce and bolstering science and technology leadership for future generations. The Institute for Student-AI Teaming is designing new approaches to AI in the classroom to boost educational outcomes, foster deeper student engagement, and foster long-term interest in STEM subjects—especially for students from communities underrepresented in STEM fields. Working closely with a diverse community of K-12 educators, students, parents, and stakeholders, researchers will deploy AI Partners to interact naturally with students and teachers to augment classroom activities. This will give students the guidance they need to learn effectively while ensuring that educators can focus on inspiring and teaching students. By supporting the development of AI-enabled tools that can be deployed in classrooms across the nation—including classrooms that are underrepresented in STEM—NSF is helping ensure that students from every community can develop their STEM talents.



Students at work. Credit: Christina S. Murrey, College of Education, University of Texas at Austin.

Platforms for Advanced Wireless Research (PAWR)

Expanding the reach of high-speed Internet connectivity is critical to boosting economic productivity, educational opportunities, and other benefits to communities around the nation. Through PAWR, NSF is partnering with a consortium of more than 35 companies to stand up four city-scale testing platforms. These platforms are in turn enabling experimentation with novel wireless concepts, protocols, technologies, and applications and services. With platforms currently based in Salt Lake City, New York City, and North Carolina’s Research Triangle, PAWR is moving forward with plans for a fourth testing platform to focus on rural broadband technology, with an eye toward reducing access costs for rural communities and integrating multiple wireless technologies in new ways to reach unserved and underserved areas.



Cell tower. Credit: ArtisticOperations/ Pixabay.

Developing a potential biofuel, identifying key switchgrass genes



Scientists' new analysis of switchgrass could be a game-changer for its use as a source of biofuel. Credit: Jason Bonnette, UT Austin

As economies move towards renewable fuels, the development of new source of clean energy – including biofuels – continues to be a critical avenue of research. In pursuit of such fuels and building on decades of NSF-supported advances in genomics, researchers have published a complex genome analysis of switchgrass, a promising biofuel crop. The analysis tied different genes to performance in varying climates across North America, enabling the development of a roadmap for breeding high-yielding switchgrass paired to current and future climate conditions across the United States. Increased switchgrass yield would increase its uses as a source of biofuel, a critical component of lowering atmospheric carbon levels and combating climate change.

Tiny optical cavities could advance quantum networks

Engineers have reached a new milestone for Quantum Information Science and the quest to create a quantum internet. The internet as we know it today is built on familiar technology like high-power microprocessors that power computation and networking infrastructure that is the backbone of connectivity, but scientists are still designing counterparts for the future of quantum computing. Funded by NSF under the Quantum Leap Big Idea, researchers have answered an important question about how quantum information can be sent and received through a quantum internet. Scientists can encode information in the quantum properties of individual atoms, which can be transmitted to other quantum computers. But how to “read” that information when it is received has been an open question until now. The researchers sculpted microscopic cavities in tiny pieces of crystal capable of holding atoms encoded with quantum information and sensing the atom’s quantum properties. Just as technology like floppy disks kickstarted the digital age in 1960s, quantum breakthroughs like this are enabling leaps forward in emerging industries.



NSF-funded researchers are working to create the building blocks of a quantum network. *Credit: The Opte Project/Wikimedia (CC BY 2.5).*

Scientists discover how cyanobacteria thrive in low light

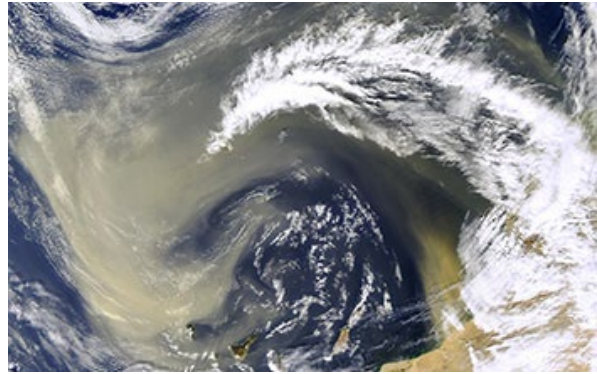
Cyanobacteria are tiny organisms that live virtually everywhere on Earth and use weak, filtered sunlight to generate energy through photosynthesis. They helped create an oxygen-rich atmosphere and continue to provide us with much of the oxygen we need to survive. Now, with funding from NSF, researchers have mapped the structure of the protein complex that allows cyanobacteria to live on such small amounts of light. The results could be used to engineer crops that thrive under low-light conditions, making the production of some crops less energy-intensive and more bountiful.



When cyanobacteria live in low-light conditions, some can switch to using far-red sunlight. *Credit: Shireen Dooling, Graphic Designer, ASU Biodesign Institute.*

Earth's atmosphere far dustier than previously believed

Underestimation of coarse dust skews models that predict global climate. Coarse dust particles warm Earth's climate by absorbing both incoming radiation from the sun and outgoing radiation from Earth's surface. These particles can impact stability and circulation within our atmosphere, which may affect atmospheric phenomena like hurricanes. The National Science Foundation found that Earth's atmosphere contains 17 million metric tons of coarse dust whereas current models only account for 4 million metric tons. "An accurate prediction of global climate change depends on understanding various components in the Earth system," says Chungu Lu, a program director in NSF's Division of Atmospheric and Geospace Sciences. "This research has furthered our understanding of climate change effects by dust, especially coarse dust, in the air."



Dust in the atmosphere swirls above the Sahara Desert. Credit: NASA.

Examining the impact of the COVID-19 Pandemic on the rural American West



The Rural West Covid Project team also plans to examine how rural communities in the West recover from the pandemic and how people's sense of community has changed. Credit: Sara Carpenter/Shutterstock.

Much has been written about the impact of the COVID-19 pandemic on urban centers and suburbs across the United States, but less discussed is its impact on rural America, especially the rural West. The NSF-funded researchers have published a paper with results of their study in the journal Proceedings of the National Academy of Sciences. The scientists present results of their first survey of over 1,000 rural Western residents, which took place from June through July, 2020 by mail, text and phone. The findings show significant impacts on health and well-being across sex, age, ethnicity, and education.

Seismic network from unlikely source

How do you detect undersea earthquakes that can potentially cause devastating tsunamis? A team of NSF-funded geoscientists has found a way to use fiber optic communications cables at the bottom of the North Sea as a giant seismic network. While placing permanent seismic monitoring equipment on the seafloor would be prohibitively expensive, the fiber optic cables that already crisscross the ocean floor—carrying telecommunications signals between continents—are a ready-made solution. By sending a beam of light along the fiber optic cable, researchers detect tiny imperfections that reflect light back, which act as “waypoints” along the cable. When a seismic wave jostles the cable, the waypoints shift slightly, changing the way light in the cable is reflected and allowing researchers to take measurements of the seismic wave. By making creative use of existing infrastructure, researchers enhance disaster preparedness while opening up exciting new ways to study the Earth.



Researchers detected an earthquake by using fiber optic cable that connects a wind farm. Credit: Riekelt Hakvoort/Shutterstock.com.

PuebloConnect: Expanding internet access and content relevance in Tribal communities

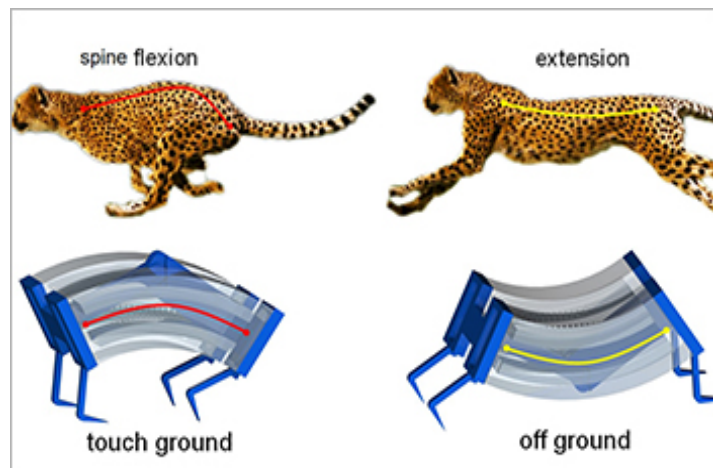


Team member Jennifer Case Nevarez of the Community Learning Network worked with K'e Infoshop to donate supplies and PPE to various groups, communities, and organizations in need during 2020. *Credit: PuebloConnect.*

Rural and Native American reservation communities in northern New Mexico have among the lowest Internet availability rates in the nation. In partnership with non-profit, Native-serving, and community organizations, CISE researchers are actively working to solve these digital inequities. The research team develops novel last-mile Internet connectivity and access solutions in tribal regions, develops community Web skills, and deploys cutting-edge technologies for connectivity and network management. The connectivity enables reservation residents to meaningfully participate in the Internet, as both consumers and producers of Internet content, in order to create new opportunities for economic development. In response to the stay-at-home orders due to COVID-19, the team has recently expanded Internet access on the Santa Clara Pueblo through installation of an innovative new base station and is working on providing a mobile WiFi hotspot to reservation residents.

Inspired by cheetahs, researchers build fastest soft robots yet

From navigating forbidding terrain in search-and-rescue missions to rapidly sorting fragile products in a warehouse environment, ‘soft robots’ have transformative potential in applications and environments that require machine assistants to have flexibility, agility, and a gentle touch. With a grant from NSF, engineers have developed a new type of soft robot that moves more than three times faster than previous designs. Inspired by the way that cheetahs derive their record speed by flexing their spine between two ‘bistable’ positions, researchers created soft robots that are faster and capable of running up steep inclines that are challenges for existing models. The engineers are already working on the next generation of their high-performing model, envisioning how their breakthrough could pave the way for multi-functional soft robots that may one day assist humans in a variety of environments.



Inspired by the biomechanics of cheetahs, researchers have developed a new type of soft robot. *Credit: Jie Yin, North Carolina State University.*

LIGO-Virgo finds mystery object in gap between neutron stars and black holes

When the Laser Interferometer Gravitational-Wave Observatory—known as LIGO—detected gravitational waves for the first time in 2016, it sent shockwaves through the scientific community, confirming predictions made by Albert Einstein a century before in a feat of research that some thought would be impossible to achieve. LIGO is continuing to make breakthroughs, detecting cosmic collisions between black holes and neutron stars, and answering key questions about our universe. One of those questions revolves around the “mass gap”—a blank space in astrophysicists’ data between the largest neutron stars ever detected and the smallest black hole. At the end of their lifetimes, larger stars collapse into black holes, while smaller stars leave behind ultra-dense neutron stars. Since normal stars come in a spectrum of sizes, astrophysicists have been puzzled by the gap between neutron stars and black holes. A new LIGO discovery in 2020 provided evidence of an object firmly in the “mass gap” range. Whether it is record-breaking neutron star or a mini-black hole, the discovery is helping scientists get a clearer picture of some of the most exotic phenomena in the universe.