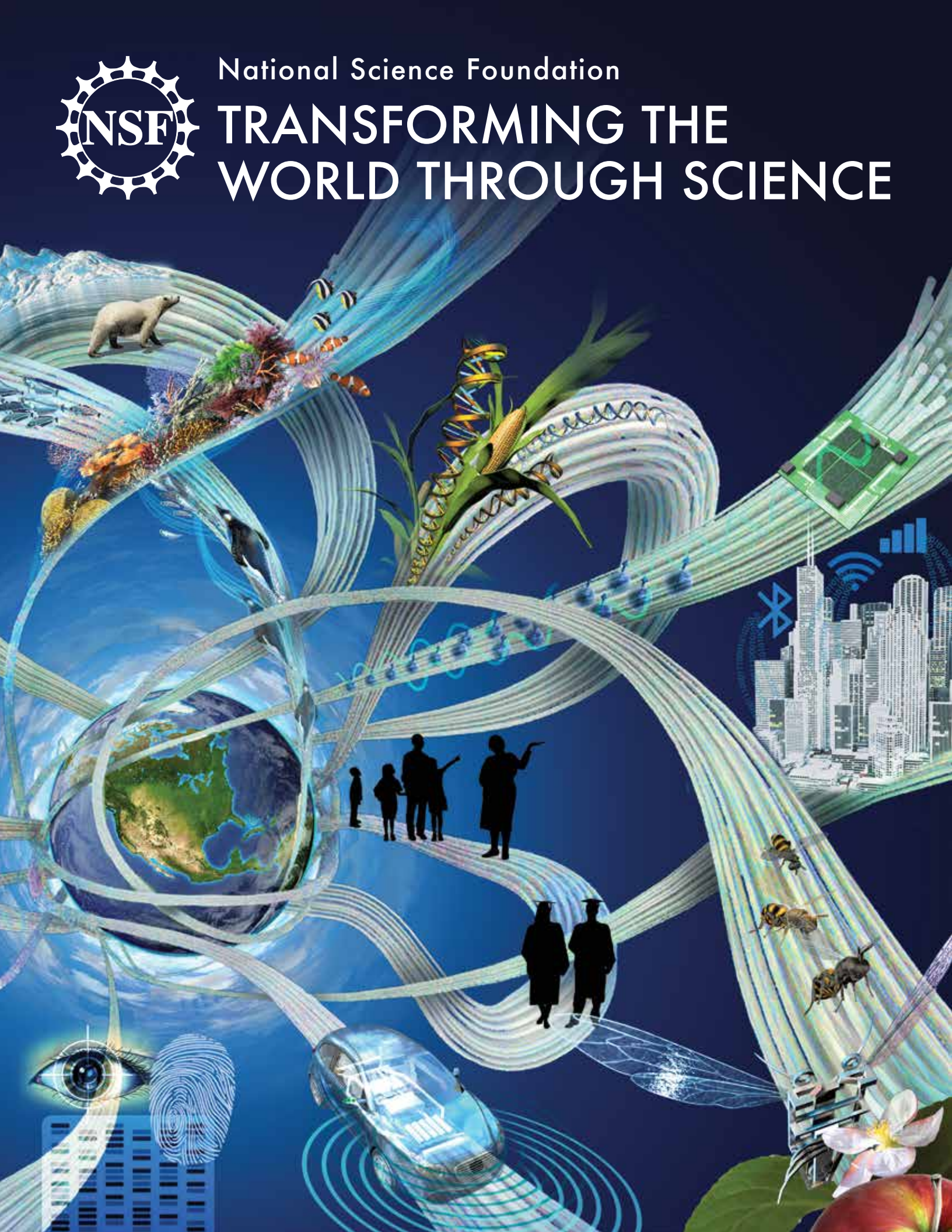
National Science Foundation

TRANSFORMING THE WORLD THROUGH SCIENCE




.anaraa.com

DIRECTOR'S LETTER

The National Science Foundation's (NSF) decades-long investment in science and engineering (S&E) research helped build the backbone of the U.S. scientific enterprise and transformed universities and colleges into centers of scientific innovation, creativity, knowledge and discovery. It also brought about the benefits of scientific discovery—new technologies, products and knowledge—that have fueled the economy, strengthened national security, enhanced the well-being of millions of Americans and shaped the nation as a world leader in science and technology.

Today, NSF-funded research continues to advance the nation's prosperity, welfare and leadership. As these pages reflect, outcomes from basic research across multiple scientific disciplines are transforming entire industries, from transportation to computing to manufacturing and agriculture.

Scientific breakthroughs start with a big idea—a question about the nature of things that leads to a fundamental shift in thinking. The ability to pursue and investigate that question, and to innovate along the way, is what enables the discoveries that ultimately transform the world.

Recently, NSF debuted a set of Big Ideas. These are bold, long-term research questions that look at critical societal challenges and aim to catalyze new breakthroughs from the S&E communities. They identify new frontier areas for basic research, from the Arctic to the quantum world, yet also underscore where greater investments are needed; for example, in the S&E infrastructure and workforce.

If one factor unites these Big Ideas, it's that they must be shared with the public by the entire scientific community committed to moving them forward. The Big Ideas also serve as invitations to other federal agencies, nonprofits, private-sector collaborators, industry partners and the public to help expand, develop and turn them into reality.

As the only agency that supports all areas of S&E, NSF is committed to moving these ideas and the S&E enterprise of the nation forward. As highlighted in this book, this involves investing in people—the cornerstone of the scientific endeavor—through programs that ensure science, technology, engineering and mathematics education and careers are accessible to all citizens. And it involves supporting a vast physical infrastructure, from telescopes and polar stations to ecological sites to cyberinfrastructure/supercomputers capable of advancing the frontiers of science.

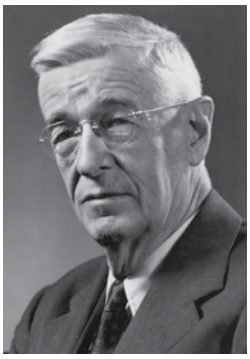
With bold leadership and an eye toward the future, the U.S. will remain at the forefront of scientific exploration.

France A. Córdova
Director, National Science Foundation

AN EXTRAORDINARY MANDATE

"The pioneer spirit is still vigorous within this Nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress."

-Science, The Endless Frontier, 1945



Vannevar Bush wrote those words in response to a commission from President Franklin D. Roosevelt to plan the nation's scientific future after the massive—and successful—research and development (R&D) mobilization following World War II. Roosevelt envisioned a postwar world with a brighter future than the preceding decades, one in which science and technology (S&T) could create more productive, more fulfilling lives for all Americans. Bush, as Roosevelt's "General of Science," proposed the nation's first science agency to transition the wartime R&D experience—which yielded new discoveries such as penicillin, radar and the atom bomb—to peacetime.

In 1950, Congress passed, and President Harry S. Truman signed, the National Science Foundation Act to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes" to continue this legacy.

More than 60 years since, many aspects of S&T, as well as social and political shifts, have altered the research landscape, but NSF has adapted and held firmly to its core mission: belief in the value of basic research. It is indeed "where discoveries begin."

TABLE OF CONTENTS

THE ARC OF SCIENCE: RESEARCH TO RESULTS

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

1. **WILDFIRE:** NSF funds research that takes a multifaceted approach to understanding wildfires from prevention and prediction of the fire's path to expanding wireless communication needed for responders to studying subsequent re-growth.
2. **ASTRONOMY:** NSF-funded facilities house some of the world's most powerful telescopes, providing new ways to peer into space to survey distant galaxies, detect cosmic particles and monitor the sun's magnetic field and solar flares.
3. **ARCTIC:** Establishing a network of mobile and fixed observation platforms and tools across the Arctic will enable NSF to understand the far-reaching consequences of changing Arctic temperatures and sea-ice levels on the climate, weather and ecosystems.
4. **OCEAN:** The oceans are a complex and dynamic environment that houses tremendous diversity and promise for improving our quality of life. NSF addresses multiple dimensions of ocean research from mapping evolving ecosystems and forecasting sea-level changes to tracking and remediating oil spills to developing new ways to harness energy from ocean waves and clean contaminated water.
5. **AGRICULTURE:** With NSF funding, researchers have developed nutrient-rich vegetables, vertical farming, and methods to monitor pest levels, and sought to better understand the relationship among food, water and energy, thus protecting and improving the food supply.
6. **QUANTUM COMPUTING:** Harnessing the power and potential of quantum mechanics and the interaction of matter and energy at extremely small and discrete dimensions enables smaller, faster, more efficient sensors and computing. Looking ahead, NSF is prepared to lead the next computing revolution by addressing fundamental questions about quantum behavior and systems.
7. **WEATHER:** NSF-funded researchers are enabling a better understanding of weather patterns and more accurate weather predictions, through Doppler Radar, the Doppler on Wheels vehicle, airborne GPS technology, tornado trackers and computer modeling.
8. **ECONOMICS:** Understanding how U.S. goods and services are exchanged is vital for growth and sustainability, a mission NSF knows well. Fifty-five of the 78 Nobel Prize winners in Economic Science were NSF-funded.
9. **EMERGING PANDEMICS:** Zika, Malaria, West Nile. When and where will the next outbreak strike? NSF-funded researchers study vital aspects of the mosquitoes, ticks, fleas and fruit bats that carry viruses harmful to humans. Researchers track their movement, life cycles as well as what attracts and repels them, to determine and limit the spread of infectious diseases.
10. **ANTARCTIC:** NSF-funded research includes ice-shelf monitoring, cosmic neutrino detection, studies of the cosmic microwave background, and life in extreme environments. NSF also operates several important components of Antarctic research: the Amundsen-Scott South Pole, McMurdo and Palmer stations. The management of these facilities, as well as NSF's unique relationship with the Department of Defense to support flight and vessel operations, play an indispensable role for the international research community to carry on their work.
11. **EDUCATION:** NSF is dedicated to STEM education, from educating teachers and cybersecurity experts and funding students to supporting tribal colleges and universities, with a special focus on workforce development and broadening participation by underrepresented groups. NSF also funds research to improve STEM education.

12. **CYBERTECH:** Imagine a connected world with a safe, fast, and accessible internet; cutting-edge anti-virus software; more energy-efficient information technology systems and software; cloud computing; and global accessibility to data. NSF is poised to make major transformations, driven by the combination of machine learning, artificial intelligence, the Internet of Things and robotics.

13. **NATURAL DISASTER:** From seismic shaking models and earthquake-resistant water pipelines to search and rescue robots to understanding the human response to emergencies to collecting data, NSF funding encompasses all aspects of natural disasters and increases preparedness and resilience.

14. **LINGUISTICS:** NSF funds research to understand the science of linguistics, including the psychological processes involved in the use of language; how children acquire language; the social and cultural factors in language use, variation and change; and the biological basis of language in the brain.

15. **BRAIN:** Understanding the brain, the most intricate organ in the body, requires the integration of multiple approaches and methods. NSF-funded researchers study how individual brain cells function and communicate with each other and how neural networks are formed and maintained, which will advance the understanding of the way neurophysiological systems operate and relate to behavior.

16. **POLICING:** Thanks to NSF research involving stronger bulletproof vests, DNA fingerprinting, retinal scans, improved explosive devise detection, work in cryptography and nonverbal communication education, our military and police are able to better perform their work and do so more safely, enhancing national security.

17. **CAR:** NSF drives the automotive field forward with research on advanced manufacturing; safer, more fuel-efficient cars and airplanes; and self-driving car technology.

18. **ROBOTICS:** From insect-sized robots to health and education assistance to robots working in tandem with humans, NSF is propelling forward the field of robotics.

INVESTING IN THE FUTURE

Today's technologies were once just ideas. In most cases it took years of research and funding to bring them to market. The advances that will change our lives require careful cultivation and NSF is a central player in this effort. Through basic research funding and educational initiatives that tap into the nation's economic drivers, NSF contributes to every step of the U.S. research enterprise.

Across—and among—its seven directorates, each one representing a broad field of science, engineering and education, NSF funds ideas that push the boundaries of innovation and productivity. With the power to transform daily life, from increasing crop yields to high-speed communication networks, these ideas are critical to moving the nation forward. Grants span all parts of the research and innovation pipeline, from fundamental research to transition to practice of research innovations. Researchers are encouraged to apply at all levels of their careers. Specific awards can assist young researchers with establishing their scientific and teaching trajectory—cementing research pathways that can transfer to commercial arenas.

Through its education programs, NSF prepares students from kindergarten through post-graduate school to become the new champions for scientific exploration. These efforts also provide evidence-based resources and learning experiences for K-12 teachers to strengthen the skills they need to nurture these budding scientists and engineers.

Advancing U.S. technological leadership also requires strong collaborations between industry and academia. Acutely aware of this need, NSF supports initiatives that complement the needs of industry, helping to transition new scientific knowledge to commercialization. Other programs work with community colleges and job training programs to strengthen the skills of technicians in high-tech fields from biotech to optics to cybersecurity, strengthening the U.S. workforce and keeping the country safe. Small businesses also benefit from these collaborations. Grants that foster entrepreneurship and provide R&D funding help them refine ideas and bring innovative products to market across all scientific fields. NSF's decades of collaboration across industry, academia and government have facilitated some of the nation's most groundbreaking and important discoveries.

DID YOU KNOW?

According to NSF's National Center for Science and Engineering Statistics (NCSES), the federal government provides 45 percent of the total national investment in basic research. This funding provides a pipeline of new ideas and innovations that are later used to bolster the economy, secure our nation and maintain our position as a global leader.

BROADENING PARTICIPATION

The brightest minds offer the best hope for solving the diverse challenges facing the world today and in the future. But who has the brightest minds? Some require a lunch subsidy. Others communicate with assistive devices. Still others live in Alaska's villages. Building a pathway for these students to share their talents is at the heart of NSF's efforts to broaden participation in STEM and to develop well prepared diverse STEM leaders.

These efforts give all students, regardless of background, gender, economic status, race, or physical ability, the opportunity to engage in STEM discovery. Through educational and informal settings, students from kindergarten through graduate school experience a range of possibilities they may otherwise never encounter. Participation builds critical thinking skills and often energizes these students to pursue further STEM opportunities. Their choices can lead to high-paying jobs with strong growth potential.

Since its inception, NSF has funded the development of STEM talent with the goals of furthering scientific discovery and ensuring the nation's security, economy and ability to innovate. NSF's recent endeavor is NSF INCLUDES. The goal of this integrated, national initiative is to develop STEM talent from all sectors and groups in society to help grow our economy.

NSF's broadening participation programs change individual lives and often entire communities. They strengthen the U.S. research enterprise and sharpen its competitive edge. Through these programs, keen minds are empowered to change the world.

DID YOU KNOW?

According to the National Center for Science and Engineering Statistics, women make up over 50% of the college-educated workforce but only 28% of individuals working in science and engineering occupations. The disparities for certain minority populations, including Blacks and Hispanics, are even larger. These numbers underscore why NSF invests in a number of programs designed to understand and broaden participation in STEM at the educational and professional levels.

MERIT REVIEW

Every year, NSF receives over 50,000 research proposals. To evaluate which proposals have the greatest potential to promote the progress of science, a rigorous merit review process was established by the National Science Board that seeks to identify two key factors in every proposal:

- Intellectual merit: the potential to advance scientific knowledge.
- Broader impacts: the potential to benefit society and contribute to the achievement of specific, societal outcomes.

Evaluating proposals on the basis of these key factors assures that the Foundations' activities are in the national interest. As reviews affirm, all proposals funded by NSF are of high quality, advance scientific knowledge and address societal needs.

For this globally-recognized gold standard for evaluation to work, NSF relies on its program directors to assemble experts to evaluate every proposal eligible for funding, either individually, on a panel coordinated by NSF, or a combination of both. Every eligible proposal is reviewed by multiple experts in that proposal's discipline(s), who provide confidential feedback, which is crucial to ensuring that unbiased, independent assessments are received. Multiple analyses of a proposal's strengths and weaknesses provide a diversity of viewpoints across all dimensions of intellectual and societal benefits.

Program directors—experts in their disciplines—use reviewers' feedback and proposal rankings to determine which proposals are most likely to achieve their stated goals and advance the nation's scientific and societal endeavors. The merit review process is one of checks and balances through multiple reviews, strict conflict of interest rules and concurrence from directorate leadership. High-level oversight groups such as committees of visitors and advisory committees provide portfolio reviews and assess the quality and integrity of NSF's decision-making processes. Information on every award is publicly accessible via the NSF website.

NSF has limited resources and is only able to award a fraction of the proposals it receives annually. Review feedback is provided to every grant proposer, whether they are funded or not. This feedback is constructive information that provides guidance towards refining the scientific ideas or proposal.

NSF's merit review process would not be what it is without the participation of nearly 34,000 reviewers each year, who provide their time and expertise to give back to their science and to the nation. This willingness to serve allows NSF to use almost all of its funds—93 percent of its total budget—to support over 362,000 researchers, teachers, postdoctoral fellows, trainees and students each year.

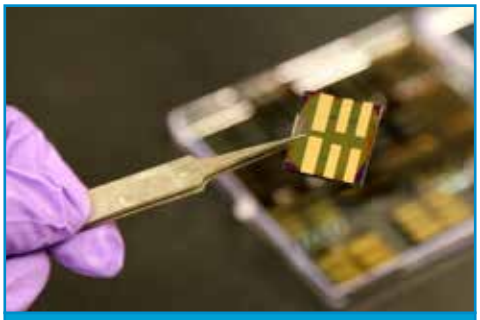
NSF BY THE NUMBERS

$7.5 B
FY 2017 actual

93%
funds research, education and related activities

50,000+
proposals received

12,000
awards funded



2,000
NSF-funded institutions

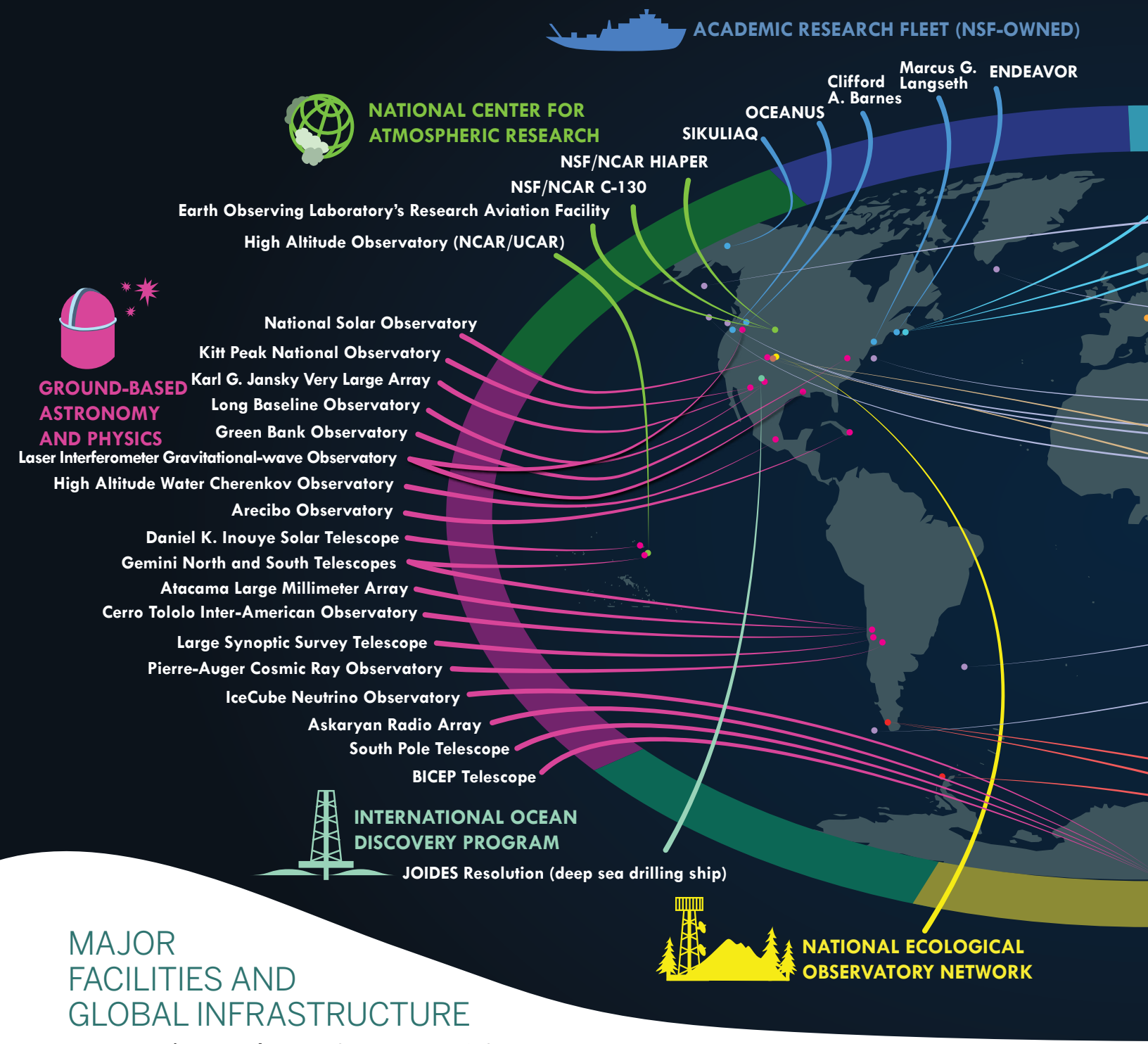
362,000
NSF-supported people

225,000
proposal reviews conducted

53,800
students supported by GRF since 1952

223
NSF-funded Nobel Prize winners

Other than the FY 2017 actual, numbers shown are based on FY 2016 activities



MAJOR FACILITIES AND GLOBAL INFRASTRUCTURE

To sustain the nation's scientific enterprise, NSF supports a wide array of research infrastructure throughout the country and around the world, from polar research stations and telescopes to a fleet of research vessels. These include:

ACADEMIC RESEARCH FLEET

NSF, in partnership with other federal agencies, supports a robust fleet of 18 academic research vessels that serve as floating laboratories, including the NSF-owned vessels featured on the map.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)

NCAR is devoted to understanding and transferring knowledge about the behavior of the atmosphere and related Earth and geospace systems.

GROUND-BASED ASTRONOMY AND PHYSICS

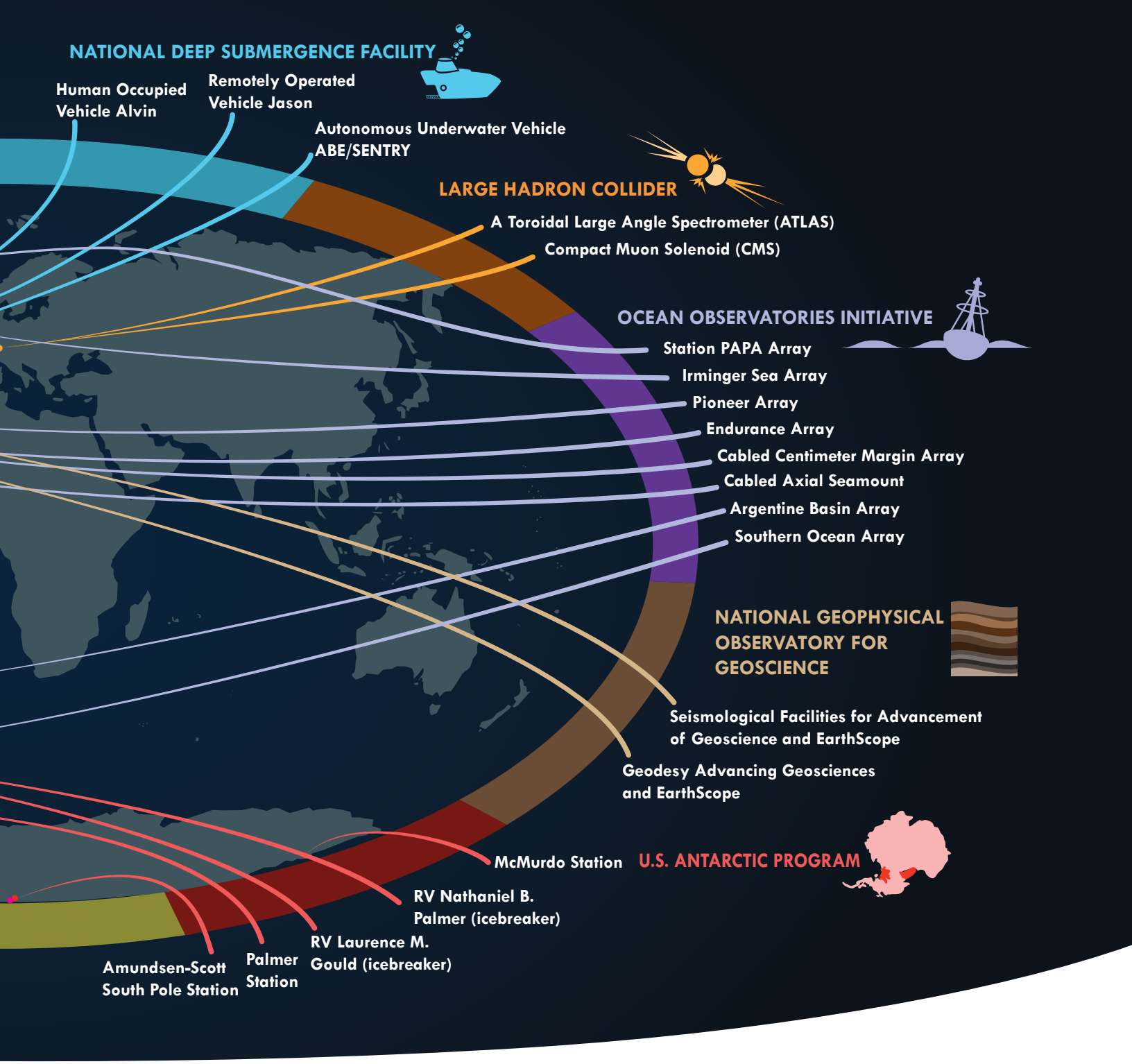
NSF funds a suite of ground-based telescopes and observatories that use cutting-edge technology to explore the universe and advance astronomical research. Many of the world's most renowned telescopes are operated by NSF.

INTERNATIONAL OCEAN DISCOVERY PROGRAM (IODP)

The JOIDES Resolution, an ocean-drilling research vessel that is part of the IODP, conducts sea drilling to study Earth's oceans and paleoclimate and maintains a number of ocean drill sites around the world.

NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON)

NEON is a continental-scale ecological observatory that enables fundamental research on biological responses to



shifting environmental conditions, land-use changes and invasive species.

NATIONAL DEEP SUBMERGENCE FACILITY

With funding from NSF, the Woods Hole Oceanographic Institute operates three deep-sea exploration vehicles: one human-piloted vehicle, one remote-controlled vehicle, and one fully autonomous vehicle.

LARGE HADRON COLLIDER (LHC)

NSF supports two particle physics detectors—ATLAS and CMS—at the LHC in Switzerland, the world's largest, most powerful particle accelerator.

OCEAN OBSERVATORIES INITIATIVE (OOI)

NSF installed fixed and mobile instruments, undersea cables and instrumented moorings that span the Western Hemisphere and measure physical, chemical, geological and biological phenomena in key coastal, regional and global areas.

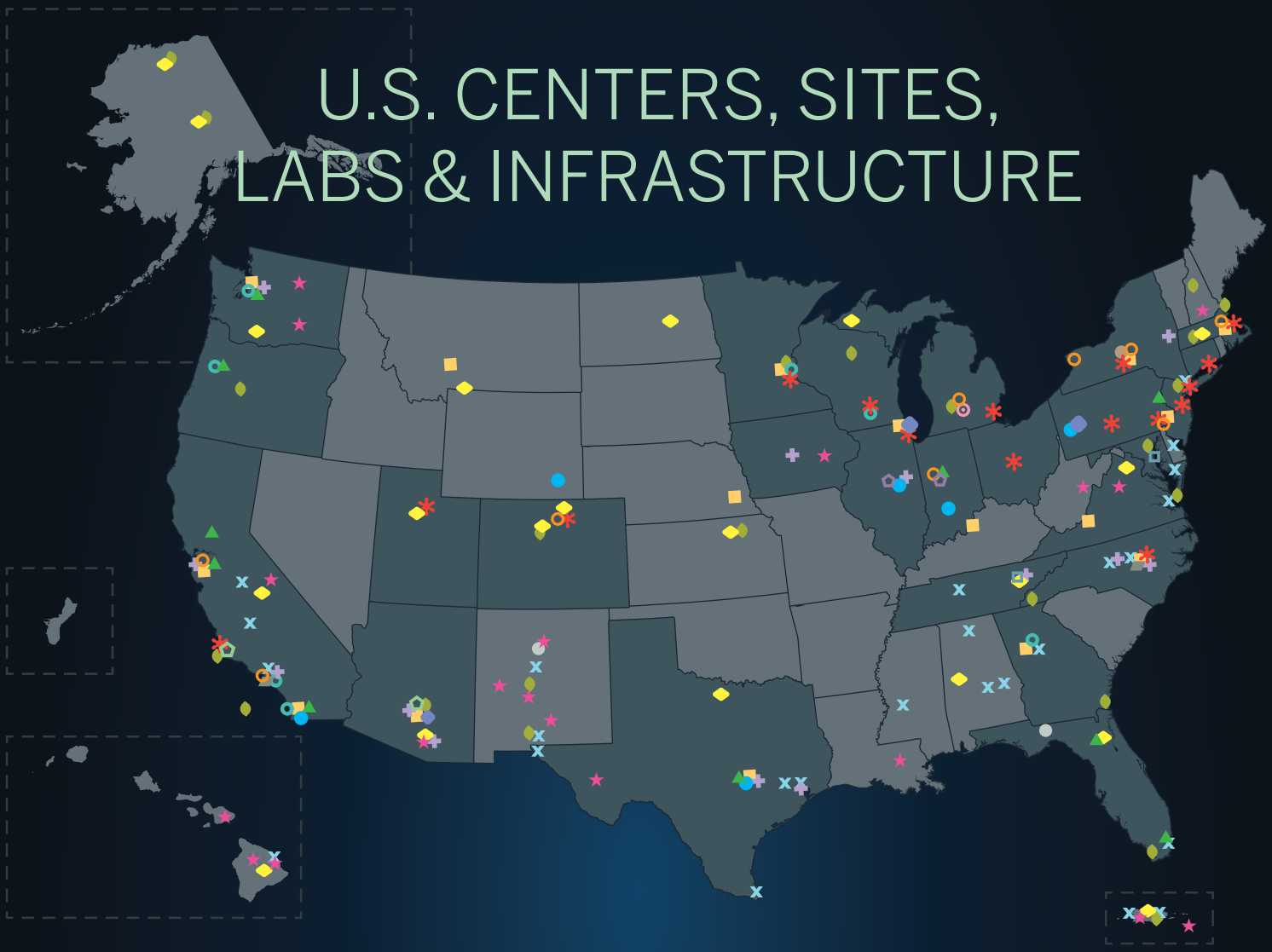
NATIONAL GEOPHYSICAL OBSERVATORY FOR GEOSCIENCE (NGEO)

Within NGEO, NSF funds a suite of community-governed, multi-user facilities that seek to transform understanding of Earth's systems and hazards.

U.S. ANTARCTIC PROGRAM (USAP)

Through USAP, NSF manages all U.S.-related logistics in Antarctica for scientific research, including deep-space exploration, particle physics, Earth's atmospheric chemistry and more.

U.S. CENTERS, SITES, LABS & INFRASTRUCTURE



- CENTERS FOR CHEMICAL INNOVATION
- CENTERS FOR ENVIRONMENTAL IMPLICATIONS OF NANOTECHNOLOGY
- CENTERS FOR NANOTECHNOLOGY IN SOCIETY
- CENTERS OF RESEARCH EXCELLENCE IN SCIENCE AND TECHNOLOGY
- CORNELL HIGH ENERGY SYNCHROTRON SOURCE
- DECISION MAKING UNDER UNCERTAINTY CENTERS
- ENGINEERING RESEARCH CENTERS
- GROUND-BASED ASTRONOMY AND PHYSICS
- HIGH PERFORMANCE COMPUTING RESOURCES (HPC)
- LONG-TERM ECOLOGICAL RESEARCH SITES
- MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTERS
- NATIONAL ECOLOGICAL OBSERVATORY NETWORK
- NATIONAL HIGH-MAGNETIC FIELD LABORATORY
- NATIONAL NANOTECHNOLOGY COORDINATED INFRASTRUCTURE
- NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY
- NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE
- NETWORK FOR COMPUTATIONAL NANOTECHNOLOGY
- SCIENCE AND TECHNOLOGY CENTERS
- SYNTHESIS CENTERS

* The light grey states on the map represent those that participate in NSF's Established Program to Stimulate Competitive Research (EPSCoR).

NSF support makes possible a network of science and engineering (S&E) centers, long-term ecological sites, laboratories, supercomputers and other infrastructure across the U.S. These resources foster scientific discovery.

BIOLOGICAL FIELD STATIONS AND MARINE LABORATORIES (FSML)

FSMLs are off-campus facilities for research and education conducted in the natural habitats of terrestrial, freshwater and marine ecosystems. NSF has provided infrastructure support to more than 300 sites across the U.S. and the world. (Sites not shown on map.)

CENTERS FOR CHEMICAL INNOVATION (CCI)

CCIs focus on solving major, long-term fundamental chemical research challenges, partnering with researchers from industry, government laboratories and international organizations. Centers include:

- Center for Aerosol Impacts on Climate and the Environment (CA)
- Center for Chemistry at the Space-Time Limit (CA)
- Center for Enabling New Technologies through Catalysis (WA)
- Center for Chemical Evolition (GA)
- Center for Selective C-H Functionalization (GA)
- Center for Solar Fuels (CA)
- Center for Sustainable Materials Chemistry (OR)
- Center for Sustainable Nanotechnology (WI)
- Center for Sustainable Polymers (MN)

CENTERS FOR ENVIRONMENTAL IMPLICATIONS OF NANOTECHNOLOGY (CEIN)

CEINs perform fundamental research and education on the implications of nanotechnology for the environment and living systems at all scales and address interactions of the living world with naturally derived, incidental and engineered nanoparticles and nanostructured materials, devices and systems.

- Center for the Environmental Implications of NanoTechnology (NC)
- University of California Center for Environmental Implications of Nanotechnology (CA)

CENTERS FOR NANOTECHNOLOGY IN SOCIETY (CNS)

NSF supports two CNS sites—at Arizona State University and University of California, Santa Barbara—which focus on the ethical, legal, economic and policy implications of nanotechnology. (AZ /CA)

CENTERS OF RESEARCH EXCELLENCE IN SCIENCE AND TECHNOLOGY (CREST)

CREST enhances the research capabilities of minority-serving institutions through the establishment of centers that effectively promote the development of new knowledge, strengthen the research productivity of individual faculty, and expand the presence of students historically underrepresented in STEM disciplines. Centers include:

- Advanced Center for Laser Science and Spectroscopy (VA)
- Bioenergy Center (NC)
- Center for Advanced Functional Materials (CA)
- Center for Cellular and Biomolecular Machines (CA)
- Center for Climate Change and Carbon Sequestration (CA)
- Center for Energy and Environmental Sustainability (TX)
- Center for Energy and Sustainability (CA)
- Center for Environmental Neuroscience (Puerto Rico)
- Center of Excellence in Nanobiomaterials derived from Biorenewable and Waste Resources (AL)
- Center for Exploitation of Nanostructures in Sensors and Energy Systems (NY)
- Center for Forest Ecosystems Assessment (AL)
- Center for Functional Nanoscale Materials (GA)
- Center for Gravitational Wave Astronomy (TX)
- Center for Innovative Information Systems Engineering (FL)
- Center for the Integrated Study of Coastal Ecosystem Processes and Dynamics (MD)
- Center for Nano & Bop-Inspired Materials and Devices (VA)
- Center for NanoBiotechnology Research (AL)
- Center for Physics and Chemistry Materials (TN)
- Center for Research and Education in Optical Sciences and Applications (DE)
- Center for Research on Complex Networks (TX)
- Center for the Sharing of Cyber-Resource to Advance Science and Education (TX)
- Center in Tropical Ecology and Evolution in Marine and Terrestrial Environments (HI)
- Center for Water and the Environment (NM)
- Computational Center for Fundamental and Applied Science and Education (NC)
- Interdisciplinary Center for Nanotoxicity (MS)
- Interdisciplinary Center of Research Excellence in Design of Intelligent Technologies for Smartgrids (NM)
- Nanotechnology Center for Biomedical, Environmental and Sustainability Applications (Puerto Rico)

CORNELL HIGH ENERGY SYNCHROTRON SOURCE

This NSF-funded synchrotron radiation facility supports research in physics, chemistry, biology and environmental and materials science. (NY)

DECISION MAKING UNDER UNCERTAINTY CENTERS (DMUU)

DMUUs are centers that support teams of researchers that will advance fundamental understanding of decision making under uncertainty. Centers include:

- Center for Climate and Energy Decision Making (PA)
- Center for Robust Decision Making on Climate and Energy Policy (IL)
- Decision Center for a Desert City (AZ)

ENGINEERING RESEARCH CENTERS (ERC)

ERCs help the U.S. meet its engineering demands and prepare the engineering workforce by integrating research and education with technological innovation. Centers include:

- Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (NC)
- Center for Bio-mediated and Bio-inspired Geotechnics (AZ)
- Center for Biorenewable Chemicals (IA)
- Center for Future Renewable Electric Energy Delivery and Management Systems (NC)
- Center for Integrated Access Networks (AZ)
- Center for Lighting Enabled Systems & Applications (NY)
- Center for Nanomanufacturing Systems for Mobile Computing and Energy Technologies (TX)
- Center for Nanotechnology Enabled Water Treatment Systems (TX)
- Center for Power Optimization for Electro-Thermal Systems (IL)
- Center for Quantum Energy and Sustainable Solar Technologies (AZ)
- Center for Re-Inventing the Nation's Urban Water Infrastructure (CA)
- Center for Revolutionizing Metallic Biomaterials (NC)
- Center for Sensorimotor Neural Engineering (WA)
- Center for Translational Applications of Nanoscale Multiferroic Systems (CA)
- Center for Ultra-wide-area Resilient Electric Energy Transmission Networks (TN)

★ GROUND-BASED ASTRONOMY AND PHYSICS

NSF supports a suite of ground-based telescopes and observatories that use cutting-edge technology to explore the universe. They include:

- Arecibo Observatory (Puerto Rico)
- Gemini Observatory (HI)
- Green Bank Observatory (WV)
- LIGO (LA/WA)
- Long Baseline Observatory (CA, NM, HI, IA, TX, WA, AZ, NH, Virgin Islands
- National Optical Astronomy Observatory (AZ)
- National Radio Astronomy Observatory (NM/VA)
- National Solar Observatory (NM, AZ, HI)

HIGH PERFORMANCE COMPUTING RESOURCES (HPC)

NSF supports HPCs throughout the U.S. that enable academic and industrial researchers, regardless of discipline or funding agency, to perform advanced analysis and simulations on everything from atoms to the structure of the early universe. They include:

- Blue Waters: National Center for Supercomputing Applications (IL)
- Bridges: Pittsburgh Supercomputing Center (PA)
- Comet: San Diego Supercomputer Center (CA)
- Gordon: San Diego Supercomputer Center (CA)
- Jetstream: Indiana University Pervasive Technology Institute (IN)
- Stampede: Texas Advanced Computing Center (TX)
- Wrangler: Texas Advanced Computing Center (TX)
- Yellowstone: NCAR-Wyoming Supercomputing Center (WY)

LONG-TERM ECOLOGICAL RESEARCH (LTER) SITES

The LTER program supports 25 sites across the country, each of which represents a major ecosystem type or natural biome and allows for the study of ecological phenomena over long periods of time. They include:

- Andrews Forest (OR)
- Arctic (AK)
- Baltimore Ecosystem Study (MD)
- Bonanza Creek (AK)
- California Current Ecosystem (CA)
- Cedar Creek Ecosystem Science Reserve (MN)
- Central Arizona-Phoenix (AZ)
- Coweeta (GA)
- Florida Coastal Everglades (FL)
- Georgia Coastal Ecosystems (GA)
- Harvard Forest (MA)
- Hubbard Brook (NH)
- Jornada Basin (NM)
- Kellogg Biological Station (MI)
- Konza Prairie (KS)
- LTER Network Communications Office (CA)
- Luquillo (Puerto Rico)
- McMurdo Dry Valleys (Antarctica, not shown on map)
- Moorea Coral Reef (Moorea, not shown on map)
- Niwot Ridge (CO)
- North Temperate Lakes (WI)
- Palmer Antarctica (Antarctica, not shown on map)
- Plum Island Ecosystems (MA)
- Santa Barbara Coastal (CA)
- Sevilleta (NM)
- Virginia Coast Reserve (VA)

MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTERS (MRSEC)

The MRSECs are an NSF-funded network of university-based centers that support materials research and education and address fundamental problems in S&E important to society. Centers include:

- Bioinspired Soft Materials Center (MA)
- Center for Emergent Materials (OH)
- Center for Materials Science and Engineering (MA)
- Center for Nanoscale Science (PA)
- Center for Photonic and Multiscale Nanomaterials (MI)
- Center for Precision Assembly of Superstratic and Superatomic Solids (NY)
- Chicago Materials Research Center (IL)
- Cornell Center for Materials Research (NY)
- CRISP Center for Research on Interface Structures and Phenomena (CT)
- Harvard Materials Research Center (MA)
- Materials Research Laboratory (CA)
- Materials Research Science and Engineering Center on Structured Interfaces (WI)
- Next Generation Materials for Plasmonics and Organic Spintronics (UT)
- Northwestern University Materials Research Science and Engineering Center (IL)
- NYU Materials Research Science and Engineering Center (NY)
- Princeton Center for Complex Materials (NJ)
- Research Triangle MRSEC (NC)
- Soft Materials Research Center (CO)
- The Laboratory for Research on the Structure of Matter (PA)
- UMN Materials Research Science and Engineering Center (MN)
- UNL Materials Research Science and Engineering Center (NE)

NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON)

NEON is a continental-scale network of sites that enable fundamental research on biological responses to shifting environmental conditions, land-use

changes, and invasive species. NEON's twenty core terrestrial sites are shown on the map.

- Caribou Creek - Poker Flats Watershed (AK)
- Central Plains Experimental Range (CO)
- Guanica Forest (Puerto Rico)
- Harvard Forest (MA)
- Konza Prairie Biological Station (KS)
- LBJ National Grassland (TX)
- Niwot Ridge Mountain Research Station (CO)
- Oak Ridge (TN)
- Onaqui-Ault (UT)
- Ordway-Swisher Biological Station (FL)
- Pu'u Maka'ala Natural Area Reserve (HI)
- San Joaquin Experimental Range (CA)
- Santa Rita Experimental Range (AZ)
- Smithsonian Conservation Biology Institute (VA)
- Talladega National Forest (AL)
- Toolik (AK)
- UNDERC (MI)
- Wind River Experimental Forest (WA)
- Woodworth (ND)
- Yellowstone Northern Range (WY)

NATIONAL HIGH MAGNETIC FIELD LABORATORY (NHMFL)

The NHMFL is the largest and highest-powered magnet laboratory in the world. (FL/NM)

NATIONAL NANOTECHNOLOGY COORDINATED INFRASTRUCTURE (NNCI)

The NNCI are university-based facilities that advance research in nanoscale science, engineering and technology by providing researchers from academia, industry and government with access to leading-edge tools and expertise. They include:

- Center for Nanoscale Systems (MA)
- Cornell Nanoscale Science and Technology Facility (NY)
- Kentucky Multi-Scale Manufacturing and Nano Integration Node (KY)
- Mid-Atlantic Nanotechnology Hub (PA)
- Midwest Nanotechnology Infrastructure Corridor (MN/ND)
- Montana Nanotechnology Facility (MT/MN)
- nano@Stanford (CA)
- Nanotechnology Collaborative Infrastructure Southwest (AZ)
- National Center for Earth and Environmental Nanotechnology Infrastructure (VA)
- Nebraska Nanoscale Facility (NE)
- Northwest Nanotechnology Infrastructure (WA/OR)
- Research Triangle Nanotechnology Network (NC)
- San Diego Nanotechnology Infrastructure (CA)
- Soft and Hybrid Nanotechnology Experimental Resource (IL)
- Southeastern Nanotechnology Infrastructure Corridor (GA/NC)
- Texas Nanofabrication Facility (TX)

NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY

This nuclear science research facility allows researchers around the world to explore the inner workings of atoms and their role in the universe. (MI)

NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE (NHERI)

NHERI centers are university-based, experimental facilities that provide researchers with state-of-the-art tools to investigate earthquake, wind and water hazards, and test ground-breaking concepts to protect individuals, communities and critical infrastructure. Different components will provide:

- Boundary Layer Wind Tunnel, Wind Load and Dynamic Flow Simulators, and Pressure Loading Actuators (FL)
- Computational Modeling and Simulation Center (CA)
- Cyberinfrastructure (TX)
- Geotechnical Centrifuges (CA)
- Large, High-Performance Outdoor Shake Table (CA)
- Large, Mobile Dynamic Shakers for Field Testing (TX)
- Large-Scale, Multi-Directional, Hybrid Simulation Testing Capabilities (PA)
- Large Wave Flume and Directional Wave Basin (OR)
- Network Coordination (IN)
- Post-Disaster, Rapid Response Research Facility (WA)
- Twelve-Fan Wall of Wind (FL)

NETWORK FOR COMPUTATIONAL NANOTECHNOLOGY (NCN)

NCN is a multi-university network that develops models and simulation tools to predict behavior at the device, circuit and system level for nanoelectronics, nanoelectromechanics and nanobio systems. NCN serves as a virtual laboratory to the nanotechnology community through online simulation and education.

- Nano-Engineered Electronic Device Simulation Node (IN)
- NanoBIO Node (IL)
- nanoHUB (IN)

SCIENCE AND TECHNOLOGY CENTERS (STC)

STCs integrate education and research and provide a rich environment that encourages future scientists, engineers and educators to take risks in pursuing discoveries and new knowledge. Centers include:

- Center for Biology with X-Ray Free Electron Lasers (NY)
- Center for Brains, Minds, and Machines (MA)
- Center for Integrated Quantum Materials (MA)
- BEACON Center for the Study of Evolution in Action (MI)
- Center for Dark Energy Biosphere Investigations (CA)
- Center for Energy Efficient Electronics Science (CA)
- Center for Emergent Behaviors of Integrated Cellular Systems (MA)
- Center for Science of Information (IN)
- Center for Bright Beams (NY)
- Center for Cellular Construction (CA)
- Center for Engineering MechanoBiology (PA)
- Center on Real-Time Functional Imaging (CO)

SYNTHESIS CENTERS

Synthesis centers accelerate scientific understanding in the development of new tools and standards for managing data, new analysis capabilities with broad utility, and foster interdisciplinary collaborations in both educational and professional contexts.

- National Institute for Mathematical and Biological Synthesis (TN)
- National Socio-Environmental Synthesis Center (MD)

DIRECTORATE FOR BIOLOGICAL SCIENCES

INTRODUCTION

Understanding life at all scales and degrees of complexity—from the sub-cellular level to the biosphere—is central to the health and well-being of humans, and to the resilience of the planet.

Basic research supported by NSF's Directorate for Biological Sciences (BIO) seeks to understand how humans and other animals, plants and a host of microorganisms persist and interact with one another, and how they respond and adapt to a variety of environmental conditions. Identifying the basic biological rules that have led to the existence and diversity of life on Earth can reveal mechanisms and inspire tools to prevent and treat diseases, improve agricultural practices or conserve precious natural resources.

In addition, new technologies have transformed biology into a "big data science," one that engages researchers from all areas of STEM to store, manage and analyze data. These data promise to enrich knowledge and address fundamental questions about everything from molecular interactions to the behavior of organisms.

Furthermore, the BIO Directorate invests in the infrastructure, tools and theories needed to advance the biological sciences and ensure the U.S. remains at the forefront of discovery, with all the technological, societal and economic benefits that a competitive edge affords. Outcomes from BIO-funded research have the ability to transform human health, food security, biodiversity conservation and more, making biology an engine for innovation in the 21st century.

Opposite page: NSF-funded researchers discovered this new species of aquatic lizard, the *Potamites erythrocularis*, while conducting a survey of a national park and its buffer zone.

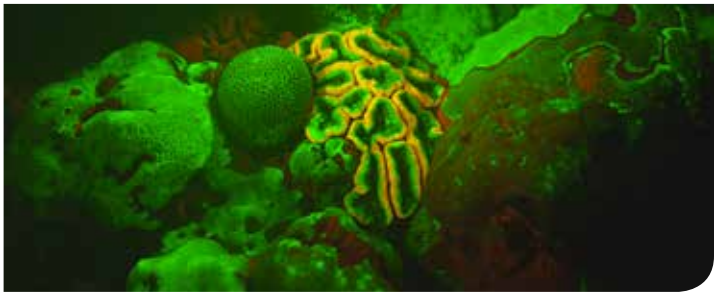
BIO DIVISIONS

Molecular and Cellular Biosciences seeks to understand complex living systems at molecular and cellular scales.

Environmental Biology supports fundamental research on populations, species, communities and ecosystems across all spatial and temporal scales.

Integrative Organismal Systems supports research to understand the simple and complex structures and functions of different organisms in evolutionary and ecological contexts.

Biological Infrastructure invests in people and infrastructure needed to advance all areas of biological research, including everything from new instrument development to advanced cyberinfrastructure.



Emerging Frontiers encourages synergy across multiple scientific disciplines to expand the frontiers of biological research.

DID YOU KNOW?

- NSF supports 25 LTER sites—each representing a major ecosystem type or natural biome—across the continental U.S., Alaska, Antarctica and islands in the Caribbean and the Pacific. Researchers have monitored five of the sites for more than three decades.
- There are an estimated 1 trillion microbial species on Earth, of which only one-thousandth of 1 percent are known to scientists. That's according to an NSF-funded study that combined datasets from government, academic and citizen science sources.
- Stanley Falkow—considered the father of molecular microbial pathogenesis, which investigates diseases at the molecular level—was supported by NSF early in his career through a series of grants. Today, Falkow is a professor of microbiology and immunology at Stanford University's School of Medicine.

IMPACTS

NEXT-GENERATION FORESTRY AND CROP MANAGEMENT

In the Western U.S., NSF-funded researchers deployed a unique set of instruments, called the Internet of Trees Micrometeorological System, to monitor how trees respond to repeated droughts at the cellular level and across ecosystems. The researchers refined the instrumentation during the study and, with funding from NSF's Small Business Innovation Research (SBIR) and I-Corps programs, began rolling it out for commercial use. The new technology, called Arable, will help farmers and natural resource managers collect data on rainfall, microclimate, etc. Pilots are underway with large growers, including California-based Driscoll's and Australian-based Treasury Wine Estates.

TOUCH-SENSITIVE PROSTHETICS

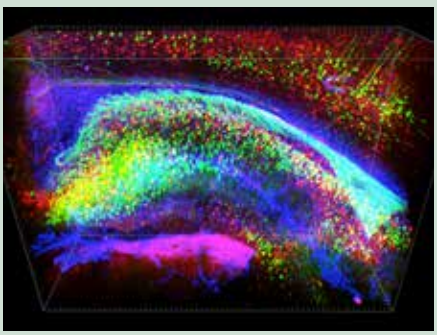
From buttoning a shirt to grasping a cup, the ability to manipulate objects is aided by the sense of touch, which is why traditional prosthetics limit patient function. Earlier this year, however, a quadriplegic man experienced the sense of touch again through a robotic arm connected to a brain computer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

NEW GENE-EDITING TOOL

NSF-funded researchers studying how a bacterium's immune system fights off viruses uncovered a powerful new gene-editing technique called CRISPR-Cas9. CRISPR-Cas9 acts like a pair of molecular-sized scissors that researchers can wield to snip a segment of DNA; for example, to edit a segment that codes for a particular trait in an organism. Biomedical researchers are exploring CRISPR-Cas9's potential use for everything from treating genetic disorders and developing targeted cancer therapies to preventing vector-borne infectious diseases. The agricultural industry is also exploring whether CRISPR-Cas9 can help enhance crop production and livestock survival.

RAPIDLY WARMING LAKES

More than half of the world's fresh water supply is warming rapidly, according to an NSF- and NASA-funded study. Using satellite data and ground measurements collected from 235 lakes on six continents over a period of 25 years, scientists determined the world's lakes are warming on average 0.61 degrees Fahrenheit each decade, with potential impacts ranging from drinking water to crop production. Toxic algal blooms are also projected to increase by 5 percent and methane emissions by 4 percent over the next decade. Some species face possible extinction, as the rapid temperature increase disrupts aquatic ecosystems.



WINDOW INTO THE BRAIN

Until recently, the composition of brain tissue limited researchers' insights into the brain's neural circuitry and function. NSF-funded scientists developed a technique called CLARITY to chemically dissolve opaque elements and replace them with a hydrogel, essentially rendering the brain transparent. When used with fluorescent markers, CLARITY lets researchers precisely reconstruct the brain's neural circuitry in 3-D and analyze how changes to the brain may underlie certain disorders such as autism or depression. The technique has been hailed as a breakthrough in neuroscience.


PARK

DIRECTORATE FOR COMPUTER & INFORMATION SCIENCE & ENGINEERING

INTRODUCTION

Advances in computer, communication and information S&E have rapidly and profoundly transformed our lives. They have changed the way we work, the means by which we communicate and the way in which many of us spend our free time. These innovations help us to be more efficient and productive, and drive economic growth.

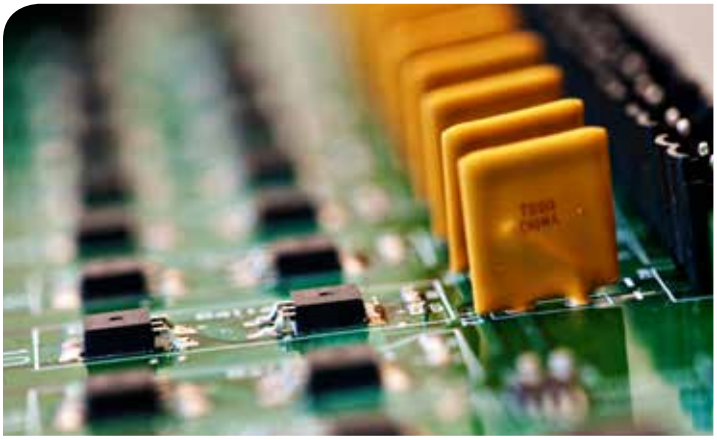
Research supported by NSF's Computer and Information Science and Engineering (CISE) Directorate has enabled many transformative innovations. From the internet and web browsers to assistive robotics and driverless cars, CISE-funded research has resulted in many technologies that touch our daily lives.

Research supported by CISE also addresses national priorities. For example, exploring the integration of physical infrastructure with "cyber" capabilities will improve the function and quality of cities and communities, revitalizing them for the 21st century. Efforts to maximize the benefits of advanced cyberinfrastructure, including high-performance computing research, development and deployment will accelerate scientific discovery and advance all sectors of the economy. And building the knowledge base and capacity for computer science education will expand its access to all students across the nation.

The computing field requires continued investment to enable more efficient and secure devices, systems, networks and computational abilities. Continued investments are needed to provide advanced cyberinfrastructure resources that enable discovery across the entire U.S. S&E enterprise. They will also enable education that provides skills essential for success in the new era of data and computation.

Opposite page: Data is accelerating the pace of discovery and innovation across all fields of inquiry. Here, sensors measure environmental data in a city to scientifically investigate solutions to urban challenges ranging from air quality to transportation flow.

CISE DIVISIONS



Computing and Communication Foundations advances computing and communication theory, algorithms for computational and data science, and the design of novel hardware and software for future computing systems.

Computer and Network Systems invests in new computing and networking technologies, while ensuring their security and privacy, and finds new ways to make use of current technologies.

Information and Intelligent Systems studies the interrelated roles of people, computers and information to increase the ability to understand data, as well as mimic the hallmarks of intelligence in computational systems.

Office of Advanced Cyberinfrastructure supports and coordinates the development, acquisition and provision of state-of-the-art cyberinfrastructure resources, tools and services essential to advance and transform S&E.

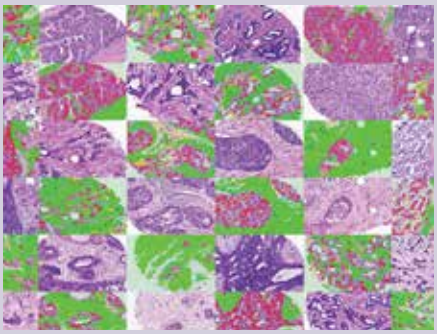
DID YOU KNOW?

- NSF supports 82 percent of U.S. academic computer science research. This funding enables research throughout the entire range of computing from fundamental theory to improving human-computer interfaces.
- The Blue Waters supercomputer at the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign is the fastest supercomputer on a university campus in the U.S. Researchers across the U.S. use Blue Waters to address a wide range of challenges, from predicting the behavior of complex biological systems to simulating the evolution of the cosmos.
- NSF-funded researchers worked with The College Board to launch a new Advanced Placement® (AP®) computer science course that aims to engage a greater number and diversity of students in computer science.

IMPACTS

ADVANCING WIRELESS COMMUNICATIONS

The growing U.S. wireless industry, which reached nearly $192 billion in 2015, relies on advances in wireless communications technologies made possible by NSF-funded research. One such advance is a discovery made in 1992 that enables wireless devices to simultaneously receive multiple input and multiple output (MIMO) data streams. MIMO technology dramatically increases the performance of wireless systems, allowing both higher data rates and wider coverage areas, and underlies today's wireless (WiFi and LTE) networks. In addition, this breakthrough was the basis for two companies that pioneered 4G wireless communications and WiMax technologies and advanced the wireless communications sector over the last decade.



TRAINING COMPUTERS TO ANALYZE CANCER

Advances in data analytics and machine learning are helping to diagnose illnesses and personalize treatments. For example, scientists developed a new model to teach computers how to analyze breast cancer. By assessing numerous novel morphological features visible in images of breast cancer tissue, the model can more accurately determine cancer diagnosis and prognosis than trained clinicians. An astounding outcome of this work was that the cellular features that were the best predictors of patient survival were not from the cancer tissue itself, but rather from adjacent tissue—a finding that had gone undetected by medical teams.

INSTRUMENTING A CITY TO TRACK LIVABILITY

New sensors, together with advanced networking capabilities, are paving the way for smart cities and communities. In Chicago, Illinois, researchers are working with the city to deploy an urban-scale instrument that can assess the livability of areas by measuring environmental data. Sensor boxes are mounted to street light poles that measure factors such as weather and air quality, and then analyze those data on the spot in order to help protect privacy. The information collected through this network of sensors is open and free to the public and is being used by individuals to guide everyday decisions. For example, an individual with asthma may plan to take the bus instead of walk on a day when the air quality is poor.

REDUCING SPAM AND STOPPING INTERNET SALES OF COUNTERFEIT PRODUCTS

In recent years, spam emails marketing products for everything from pharmaceuticals to software have begun flooding our inboxes. Sophisticated firewalls can filter out these messages but some still slip through, with some recipients unknowingly buying the advertised—often counterfeit—products. Researchers performed a detailed analysis tracking the financial trail of these sales and showed that only a handful of banks process these transactions. Limiting those transactions disrupted the spam networks, substantially reducing emails advertising the sale of such products. As a result of this work, the International AntiCounterfeiting Coalition launched a program to help banks identify and halt payments from spammers selling counterfeit products.

ENGAGING STUDENTS THROUGH PERSONALIZED ROBOTS

A furry, brightly colored robot named Tega is helping to teach Boston-area. The robotic system was designed and piloted with NSF funding to enable long-term interactions with children by interpreting the emotional response of an individual and, based on those cues, create a personalized motivational strategy. It uses an Android device to process movement, perception and thinking and respond appropriately to children's behaviors. Tega was more engaging than other non-personalized learning robots. The researchers hope to make improvements to the personalized educational assistive robot so that it can be used in a variety of contexts, including assisting students with learning disabilities.


West Marine

DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES

INTRODUCTION

People are the backbone of the nation's S&E enterprise. The success of that enterprise relies on scientists, technicians, engineers, mathematicians and educators who engage in science every day, combined with a well-informed public.

To sustain U.S. leadership and excellence in STEM, and to meet the high-technology workforce needs of today and tomorrow, the U.S. must maintain a vigorous investment in its STEM human capital.

NSF's Education and Human Resources (EHR) Directorate supports STEM education and education research from early childhood learning to doctoral work and beyond. EHR supports and promotes evidence-based innovations in teaching practices, instructional tools and programs that advance STEM education and prepare the next generation of STEM professionals.

The directorate further works to ensure that STEM education and career opportunities are available to all Americans, regardless of race, creed or gender. Accordingly, EHR-based programs support broadening participation and the development of talent among groups that have been traditionally underrepresented in STEM, including women, minorities, persons with disabilities and veterans.

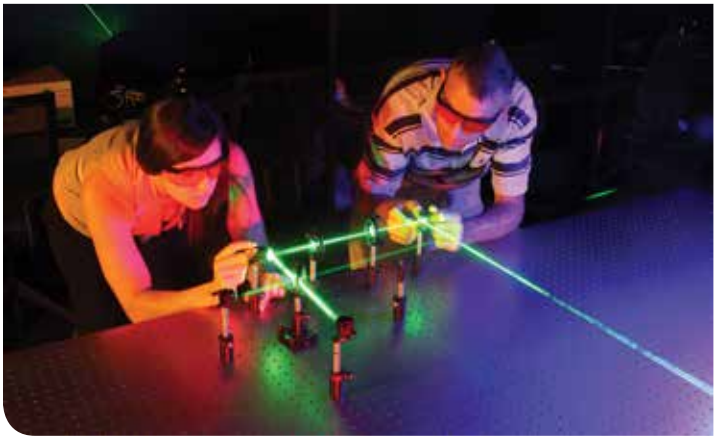
The short-term impact of this investment is to expand the STEM education research knowledge base and develop tools and practices that inform efforts toward improvement. The longer-term impact of this investment is a workforce that is diverse, innovative and prepared to lead in S&E, along with a science-literate U.S. public.

Opposite page: San Diego's Ocean Discovery Institute provides a tuition-free program to low-income youth that incorporates education, scientific research and lessons on environmental stewardship. NSF, on behalf of the White House, recognized the institute with a Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring award.

EHR DIVISIONS

Graduate Education manages innovative, NSF-wide programs to support U.S. citizens and permanent residents to become leading scientists and engineers.

Research on Learning in Formal and Informal Settings supports advances in cutting-edge knowledge and practices in formal and informal educational settings to advance STEM learning for people of all ages.



Undergraduate Education promotes excellence in undergraduate STEM education at two- and four-year colleges and universities by investing in R&D to produce effective instructional approaches and materials; research experiences; and support for diverse students and institutions to prepare tomorrow's STEM workers.

Human Resource Development enhances excellence in S&E education and high-quality research by broadening participation in STEM to include historically underrepresented groups such as minorities, women and persons with disabilities.

DID YOU KNOW?

- NSF has supported 53,800 graduate student researchers through its Graduate Research Fellowship Program (GRFP) since it launched in 1952. More than 40 of those fellows went on to become Nobel Laureates.
- Since the Sept. 11 terrorist attacks, NSF has supported the training of 2,200 cybersecurity experts through the CyberCorps®: Scholarships for Service program, which seeks to recruit and train the next generation of information technology professionals.
- Active participation in science labs not only helps students learn and earn higher test scores, but also shows a lasting physical impact on the sensorimotor regions of the brain.

IMPACTS

MATH ASSIST

Web-based platforms enhance teaching and learning in the classroom. Today, 100,000 schools across the U.S. use an online mathematics tutoring and assessment program developed by an NSF-funded researcher 15 years ago. Called ASSISTments, the innovative platform helps students with their mathematics coursework and teachers with their mathematics instruction. In Maine, a recent study of more than 2,800 students at 43 public schools using ASSISTments found that students scored 75 percent higher on a standardized test of mathematics achievement than students at schools without the program.

NSF FELLOWS MAKE DISCOVERIES

Through its GRFP, NSF has funded thousands of graduate researchers, many of whom have made important discoveries while still in graduate school. For example, an NSF Graduate Research Fellow developed a touch screen to recognize multi-finger gestures for computer input—using two fingers on a screen to zoom in and out—a breakthrough technology that is now ubiquitous in smartphones and other mobile devices. Since 1952 this program has supported 42 students who went onto win Nobel Prizes.

NATIVE STUDENTS GRADUATING WITH ADVANCED SCIENCE DEGREES

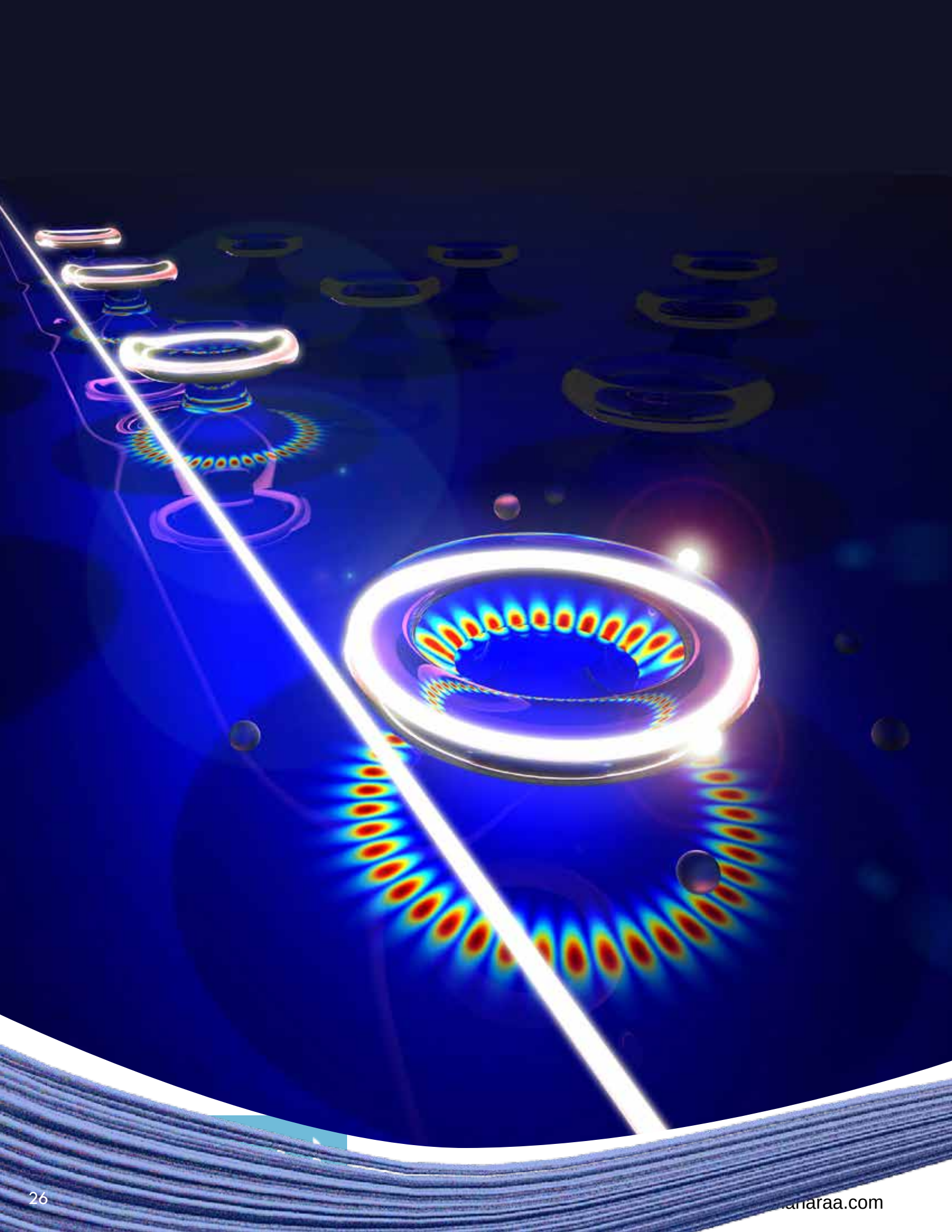
Northwest Indian College in Washington state offers one of the few bachelor of science in Native environmental science programs in the world. Supported by NSF's Tribal Colleges and Universities Program (TCUP), the first student enrolled in the program graduated in 2009. Since then, 51 students have graduated from the program, with 10 more on track to graduate in 2017, and another 81 currently enrolled. Six of the 2016 graduates are pursuing advanced degrees and the first Ph.D. graduate will return to the college as a faculty member.

VISUALIZING DATA

The U.S. Census Bureau's Census Explorer is an online, interactive mapping tool that enables members of the media and public to visualize census data at the state, county and neighborhood levels. The web-based platform is built on a data visualization tool, called Social Explorer, developed by an NSF-funded researcher to help undergraduate sociology students studying demography better visualize U.S. census data. Census Explorer users can create maps on a range of data, including median household income and home ownership rate. Within the first few months of its launch, more than 100,000 users had created 4 million data maps.

TOMORROW'S COMPUTER PROGRAMMERS

To increase the appeal of computer programming for young people, a team of NSF-funded researchers created a visual computer programming language, called Scratch, that allows users to develop software graphically instead of tediously typing lines of code. Launched in 2007, Scratch helps children improve their mathematics, computation and problem-solving skills, even as they create games, animations and other fun projects. More than 800,000 students have shared their projects through the Scratch website and in 2009, NSF-funded researchers launched ScratchEd, an online resource for Scratch educators used by teachers all over the world.



DIRECTORATE FOR ENGINEERING

INTRODUCTION

Engineering is essential to create a future where people thrive. Today, engineers are making this future a reality through research in areas such as advanced manufacturing, health care, sustainability and infrastructure.

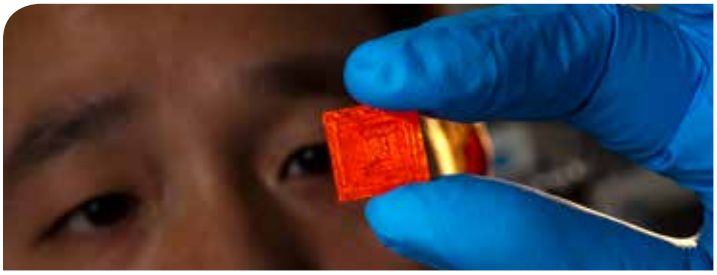
Engineering researchers create new knowledge, concepts and designs that become technological breakthroughs and solve real-world problems. They create innovations for clean water, the electric grid, agriculture and other national challenges. They make economic opportunities in areas such as 3-D printing and secure wireless communication. Engineers improve people's lives with everything from smart transportation to prosthetic devices to faster computers.

NSF's Directorate for Engineering (ENG) supports discovery across all these areas and more. To speed innovations to the market, ENG also spurs entrepreneurship, small business growth and industry collaboration. To prepare the engineers and leaders of tomorrow, the directorate supports engineering education and introduces the exciting possibilities of engineering to the next generation.

Investments in engineering are critical building blocks for the nation's future prosperity, security and global competitiveness.

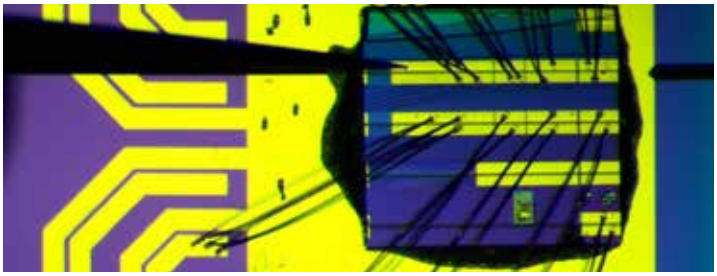
Opposite page: When visitors whisper by an arch in New York's Grand Central Terminal, sound waves travel to the arch's opposite side and are easily heard. Using the geometry of whispering galleries with light waves, new sensors magnify the effects of airborne particles and detect molecules and viruses with unprecedented sensitivity.

ENG DIVISIONS

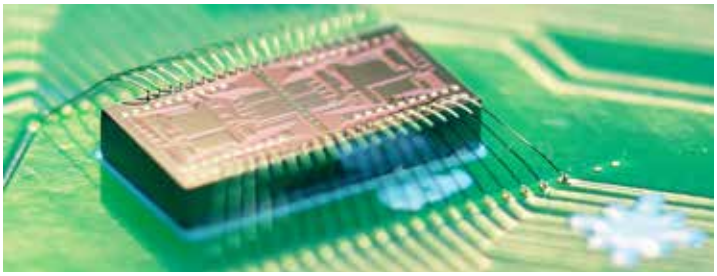


Chemical, Bioengineering, Environmental and Transport Systems supports discoveries in chemical and biochemical engineering; fundamental engineering inquiries into energy and matter; environmental engineering and sustainability; and the engineering of health care technologies.

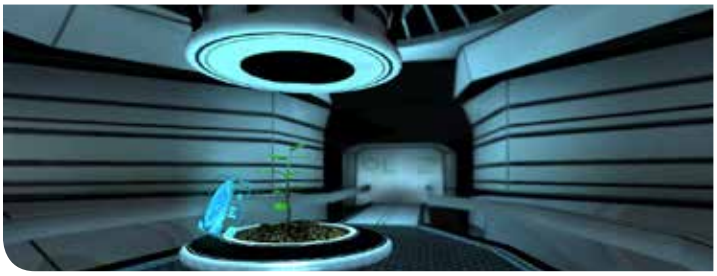
Civil, Mechanical and Manufacturing Innovation advances the future of manufacturing; the design of innovative materials and building technologies; the creation of resilient and sustainable infrastructure; and high-performance systems from robotics to health care.



Electrical, Communications and Cyber Systems promotes fundamental research in device and component technologies, power, controls, computation, networking, communications and cyber technologies for the intelligent systems of the future.



Emerging Frontiers and Multidisciplinary Activities supports research on cutting-edge opportunities and long-term challenges that address national needs, such as secure, next-generation communication and electronics; and supports studies and facilities at the intersection of engineering and other disciplines.



Engineering Education and Centers invests in the creation of 21st century engineers and technologies through center-based research; research in education and student inclusion; and research opportunities for students and teachers.

Industrial Innovation and Partnerships invests in high-tech, small businesses and collaborations between academia and industry to transform discoveries into innovative commercial technologies with societal benefits.

DID YOU KNOW?

- Since 2013, the small business innovation research (SBIR) program funded nearly 1,300 high-tech startups and small businesses, and acquisitions and initial public offerings of NSF-funded companies totaled a published dollar value of $700 million.
- Between the years 1985 and 2016, NSF-funded ERCs received 789 patents.
- NSF's Innovation Corps (I-Corps) program has immersed 800 teams of scientists and engineers from 192 universities in 44 states in entrepreneurial training to extend their focus beyond the lab and consider the commercial potential and broader impact of their research. As a result, I-Corps participants have launched 320 startups, which have raised an additional $93 million in follow-on funding.

IMPACTS

HONEY BEE RESEARCH SETS GLOBAL SERVER MARKET ABUZZ

Researchers mimicked the food foraging behavior of honey bees to vastly improve how computer programs and devices work together in a rapidly growing global market worth over $50 billion. Just as honey bees perform various tasks in a highly synchronized and adaptable manner to benefit the colony, the researchers designed a novel set of step-by-step instructions to assign tasks to multiple computer servers. Major web hosting companies use the algorithm to analyze images, recognize objects and text, retrieve documents, and more. The algorithm also affects statistics, machine learning, data mining and other areas of computer science and engineering.

MINNESOTA COMPANY TARGETS FUTURE ORGAN REPLACEMENT

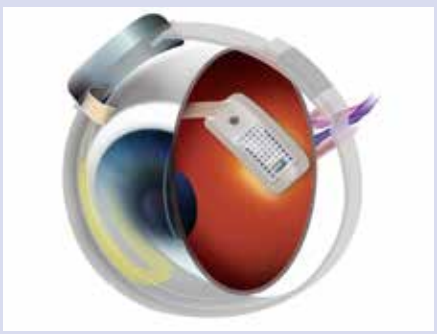
Miromatrix Medical, a small business funded by NSF, developed a technology to create bioengineered organs for human transplant. More than 120,000 people are on the U.S. organ transplant waiting list. The technology removes all cells from existing human or animal organs while preserving the material's architecture, leaving the decellularized organ ready to receive new cells from the recipient, thereby minimizing potential rejection. FDA approved Miromatrix's proprietary technique for use in a commercially-available, biological mesh for hernia repair. The company's goal is to engineer replacement hearts and other organs. It currently is developing a cardiac patch to repair damage from heart disease.

MORE RELIABLE TRANSMISSION USED IN 30 MILLION VEHICLES

Automatic transmissions allow cars and trucks to travel at sustained speeds. Their core technology, the one-way clutch, at one point failed more than any other component in Ford automobiles. Los Gatos, California based Epilogics, a small business funded by NSF's SBIR program, developed a newer Mechanical Diode One-Way Clutch and licensed it to Means Industries. Means used it to replace the older one-way clutch, and it became the most successful, active, driveline component. The Mechanical Diode One-Way Clutch has been installed more than 30 million times.

ECONOMIC WIN FOR SOLAR ENERGY CONSUMERS

SolarBridge, an Austin, Texas-based company founded by NSF-funded researchers, engineered an elegant solution that drives down homeowner costs for solar panel installations. Solar panels need devices called "inverters" to transform direct current electricity from sunlight into alternating current for home and commercial use. Usually, these inverters look like bulky boxes mounted on roofs or the sides of buildings. SolarBridge fits small inverters right onto individual solar panels. In 2014, SunPower Corp, a billion-dollar solar company, acquired SolarBridge. Today, the majority of SunPower solar panels for residential use include SolarBridge microinverters that drive down costs and installation time.



BIONIC EYE SEEING MORE USE

The first bionic eye approved for people in the U.S. has been implanted more than 200 times, a 150 percent increase from 80 successful implants overall, recorded in 2014. The Argus® II Retinal Prosthesis System allows patients to perceive light, sense movement and navigate their surroundings. Developed in part with NSF support, Argus® II wirelessly transmits images from an eye-glass-mounted camera to a tiny antenna implanted on a patient's damaged retina. From there, electrical signals are sent via the optic nerve, and the brain interprets a visual image. Argus® II is the basis for the Orion™ I Visual Cortical Prosthesis, a next-generation wireless visual cortical stimulator that was successfully implanted and activated in a human in October 2016.

DIRECTORATE FOR GEOSCIENCES

INTRODUCTION

The Geosciences (GEO) Directorate supports research that reveals what goes on beneath the Earth's crust, across its landmasses and oceans, amid the atmosphere and inside its ice floes. GEO-funded researchers seek to understand the many processes that affect the global environment.

Some of these efforts rely on NSF's fleet of research vessels while others rely on highly-equipped laboratories. Researchers travel to the South Pole, the North Pole and down deep into the world's oceans. They identify the forces behind natural hazards such as earthquakes, tornados and tsunamis. Their findings provide data for models and other tools that save lives and protect property. Solar studies illuminate the impact solar eruptions can have on Earth, disrupting everything from electrical grids to wireless communications.

The GEO Directorate also has multiple education and outreach programs to help build a strong scientific workforce, including weather forecasters, groundwater specialists, oceanographers, glaciologists, seismologists and engineers and scientists in the oil, gas, petroleum and mining industries.

Relationships with outside partners also leverage and extend the reach of GEO-funded research. The directorate is a key player in multiple activities including the Antarctic Treaty System, the U.S. Global Change Research Program, the Ocean Research Priority Plan and the Global Seismic Network.

Opposite page: NSF research in the geosciences examines the Earth's atmosphere, landmasses, oceans and polar regions.

GEO DIVISIONS

Atmospheric and Geospace Sciences extends understanding of the behavior of Earth's atmosphere and its interactions with the sun.

Earth Sciences examines the structure, composition and evolution of the Earth, the life it supports and the processes that control them.

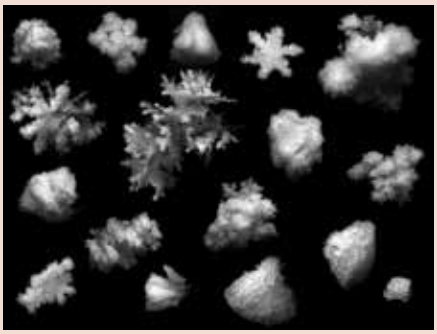
Ocean Sciences advances understanding of oceans across the globe and their interactions with people, the Earth and the atmosphere.

Office of Polar Programs has two science sections—one for the Arctic and the Antarctic. A third section manages the logistics and support operations including field stations, camps, laboratories, ships, and airplanes.

DID YOU KNOW?

- For 60 years, NSF has maintained an uninterrupted presence in Antarctica. NSF's U.S. Antarctic Program oversees all U.S. scientific research and logistics at the South Pole.
- In Southern California, NSF-supported scientists recently discovered and mapped the Salton Trough Fault, a potentially significant fault that lies along the eastern edge of the Salton Sea and runs parallel to the San Andreas Fault.
- The IceCube Neutrino Observatory is built into a cubic kilometer of ice under the South Pole. It searches for particles from the most violent sources in the universe such as exploding stars, gamma-ray bursts, black holes and neutron stars to tell us about the nature of the universe.

IMPACTS



SAFER WINTER DRIVING WITH SNOWFLAKE IMAGING

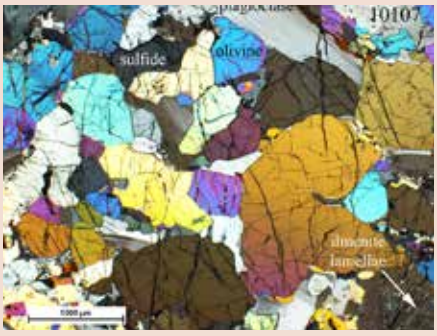
Falling snow makes winter driving a challenge. Transportation planners, road crews and emergency managers can now estimate real-time accumulations with active imaging from multi-angle snowflake cameras (MASC). NSF-funded research led to development of MASC, which images snowflakes down to the diameter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

REDUCING AIRLINE ICING EVENTS

Each year in the U.S., 20 to 40 aircraft accidents are linked to in-flight icing. Hazardous conditions that set up these events cost the aviation industry an estimated $20 million annually in injuries, aircraft damage and fuel. Icing forecast products developed by NSF-funded scientists and used by the Federal Aviation Administration (FAA) are credited with preventing an average of eight airline accidents a year and reducing airline operating costs by $60 million annually. Online icing maps, developed at the request of the FAA, represent a major advance in the nation's effort to ensure safe flying.

TRADING WATER RESOURCES ONLINE

By 2025, two-thirds of the global population could face water shortages. Conflicts over water resource management are increasing, with large sums spent on litigation. To ease these challenges, Mammoth Trading launched an online market system to lease water rights. Mammoth grew out of NSF-funded research on the economic and environmental effects of groundwater pumping rights. It provides new risk management tools for farmers, reduces the cost of water reallocation, and leads to an increase in agricultural productivity and profits, while maintaining or improving environmental conditions and resource sustainability. The approach could extend to other natural resources as well.

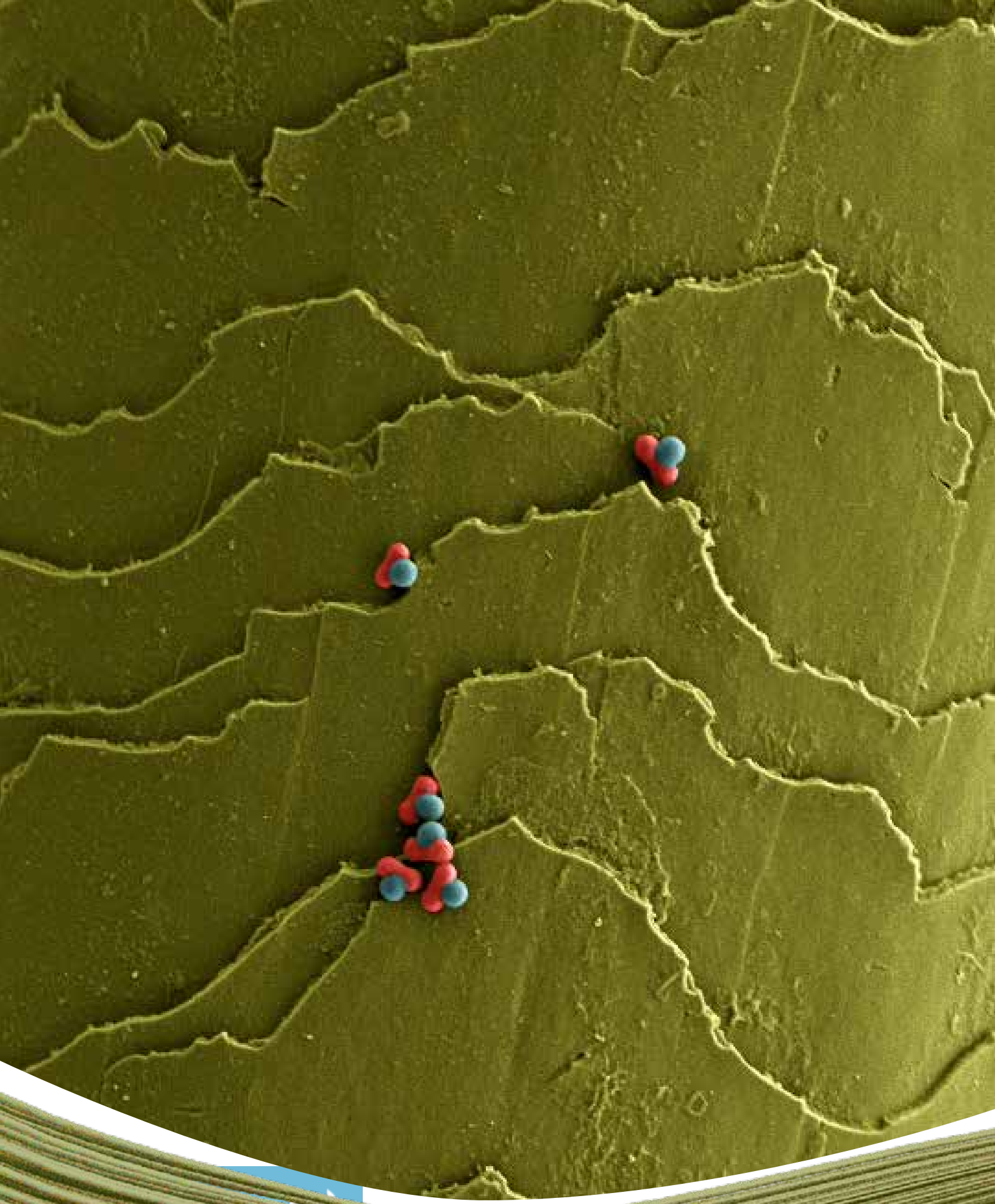


3-D GEOLOGIC MAP LEADS TO PRECIOUS METAL DISCOVERY

Using technology for 3-D electronic mapping originally developed by scientists working in the McMurdo Dry Valleys of Antarctica, NSF-funded researchers discovered one of the world's largest precious metal deposits in northern Minnesota. The Nokomis Deposit is estimated to contain metal resources of approximately 10 billion pounds of copper, 3.1 billion pounds of nickel, 165 million pounds of cobalt, 4 million ounces of platinum, 9 million ounces of palladium and 2 million ounces of gold.

LEARNED FROM AGING CORALS

Using genetics to estimate the age of corals, NSF-funded researchers have found that while some species have lasted thousands of years, their ability to continually adapt to changing conditions may be limited. Elkhorn corals found in Florida and the Caribbean were pegged at more than 5,000 years old. Their resilience attests to their abilities to adjust to sea-level changes, storms and sedimentation events. The research findings could help shape future approaches to coral reef preservation to protect these robust invertebrates.



DIRECTORATE FOR

MATHEMATICAL AND PHYSICAL SCIENCES

INTRODUCTION

Gravity, light, sound and energy. These basic physical phenomena lie at the heart of research supported by the Mathematical and Physical Sciences (MPS) Directorate. Through its five divisions, which cover astronomy, chemistry, materials, mathematics and physics, MPS-funded scientists explore how physical phenomena impact matter. They deepen awareness of mathematical concepts and develop new tools to study the physical world.

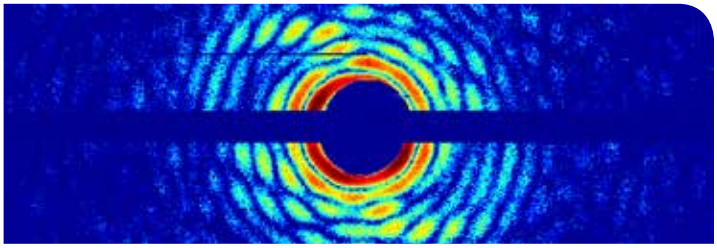
MPS is NSF's largest directorate and its research ranges across the entire scale of the universe from spinning subatomic particles to colliding black holes in space. Its award portfolio extends from large facilities, such as telescopes, to research grants for individual scientists. It includes education programs to help students pursuing careers in mathematics and the physical sciences as well as initiatives to improve science literacy.

The discoveries from this research advance the understanding of the world around us and provide the critical information needed to create technologies to improve our quality of life. Computers run faster, threats are detected sooner, water is cleaner and surgery is more precise because of fundamental studies supported by the MPS Directorate.

Opposite page: Shown in color, microscopic particles are building blocks used to create synthetic materials. NSF-funded researchers developed a process that transforms the particles from inflexible Lego-like pieces into supple, shape-shifting units.

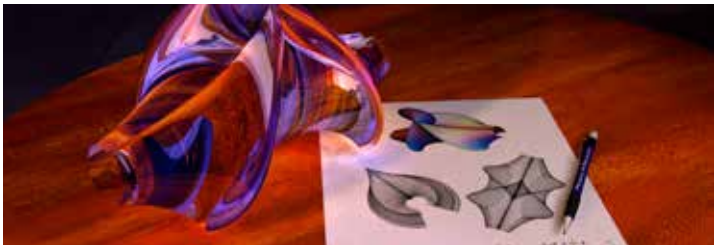
MPS DIVISIONS

Astronomical Sciences supports research in all areas of astronomy and astrophysics as well as related multidisciplinary studies.



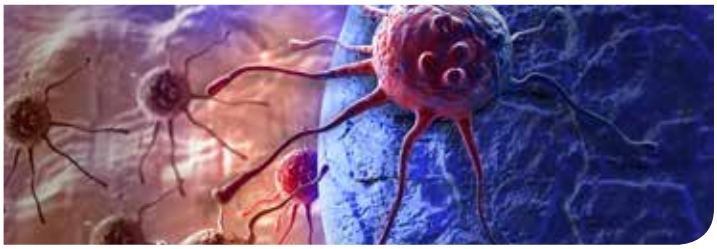
Chemistry supports innovative research in the chemical sciences to understand the composition, energetics and interactions of molecules.

Materials Research enables new experimental and theoretical discoveries about the behavior of matter and materials. The division supports the creation of new materials and new instrumentation to investigate materials phenomena, while also preparing the next generation of materials researchers.



Mathematical Sciences supports a wide range of projects aimed at developing and exploring the properties and applications of mathematical structures.

Physics sponsors research across a broad range of topics including atomic, molecular and optical physics, gravitational physics, particle physics, astrophysics and cosmology, accelerator science, plasma science, nuclear physics, and the physics of living systems.



Office of Multidisciplinary Activities facilitates and supports opportunities that cross traditional disciplinary boundaries. The office is a focal point for external partnerships, interdisciplinary research and innovative experiments in education that may lead to new paradigms in graduate and undergraduate education in the mathematical and physical sciences.

DID YOU KNOW?

- Since 1950, NSF has funded 123 Nobel Prize winners in physics and chemistry.
- Once complete, NSF's Large Synoptic Survey Telescope will contain the world's largest digital camera, with over 3 billion pixels of solid-state detectors.
- The Laser Interferometer Gravitational-Wave Observatory (LIGO) detected ripples in the fabric of spacetime originating over a billion light years away. This is the dawn of a new era of observations whose increasing number will extend our knowledge of the universe.

IMPACTS

ARTIFICIAL INTELLIGENCE MEETS BIG DATA

By 2019, big data and business analytics sales are expected to pull in $187 billion worldwide. Already making waves in this sector is Ayasdi, a company founded by a renowned mathematician and NSF award recipient. The Menlo Park, California, company analyzes large datasets using advanced algorithms. Ayasdi's analysis tools help hospitals deliver better care, health insurers streamline claims and global banks model risk. In 2015, FastCompany named Ayasdi one of the top 10 most innovative companies in Big Data.

SMART MATERIALS THAT RECOGNIZE PATTERNS

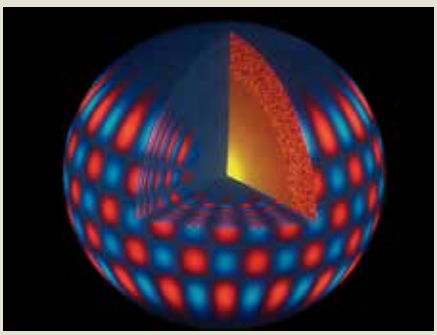
Gloves that monitor an injured hand for progress of recovery; footwear that analyzes the gait in people at risk for early onset Alzheimer's disease; and shirts that chart cardiovascular activity in people at risk of heart disease and stroke may all be possible thanks to a new material designed by NSF-funded researchers to recognize simple patterns. The hybrid gel material works by converting its own chemical reactions into electrical energy. This aspect also makes the material useful as skin for a robot or other device.

MORE ECONOMICAL FERTILIZERS

The Haber-Bosch process produces 100 million tons of fertilizer a year. This production helps feed almost a third of the world's population. Currently, the process consumes 3 to 5 percent of the world's natural gas production, about 1 to 2 percent of the world's annual energy supply. NSF-funded scientists are developing new molecular receptors that could help reduce dependence on this energy-hungry process. The receptors serve as nitrogen sensors to provide for more efficient and economical application of fertilizers, while minimizing wastewater runoff from agricultural fields.

ULTRASENSITIVE DETECTOR FOR PHYSICS AND MEDICINE

NSF-funded research to discover new fundamental particles and forces has led to a new tool with multiple applications including brain research, diagnosis of abnormal heart rhythms and pre-surgical imaging. Originally built to precisely measure very faint magnetic fields for basic physics experiments, the ultrasensitive detector, called an atomic spin magnetometer, has validated fundamental theories about the symmetry of space. Furthermore, the device's ability to sense magnetic fields 1000 times weaker than those in the human brain made it a candidate for additional applications in medicine and neuroscience. Two startup companies, TwinLeaf Precision Sensors and QuSpin, are advancing the technology for commercial use.



SOLAR RESEARCH PROTECTS CIVIL INFRASTRUCTURE

Space weather can disrupt radio and satellite communications, civil aviation and even pose a threat to the electrical grid. But solar storms are highly unpredictable. To develop solar storm forecasts, the national Space Weather Prediction Center now uses data supplied by the Global Oscillation Network Group (GONG), an NSF-funded project. The worldwide network of six telescopes monitor subtle oscillations of the sun 24 hours a day. GONG research has developed an understanding of the sun's internal structure that is used to monitor and predict activity that will lead to solar storms, even when that activity is on the side of the sun facing away from the Earth.

DIRECTORATE FOR SOCIAL, BEHAVIORAL AND ECONOMIC SCIENCES

INTRODUCTION

There are close to 7.5 billion people on the planet, each interacting with family members, friends, co-workers, communities and the environment. New technologies and forms of communication have further connected people with one another around the world at an unprecedented scale. Every day, people shape, and are shaped by, the economic, political, social, cultural, technological and environmental forces that surround them.

The social, behavioral and economic sciences collectively examine this confluence of forces on people and illuminate the fundamental principles underlying human behavior—from how we think and learn to how we interact individually and in groups. They help to better navigate relationships, build stronger and safer communities, run businesses efficiently and effectively, and create the technologies that enrich our lives.

NSF's Social, Behavioral and Economic Sciences (SBE) Directorate coordinates insights from the various disciplines to generate a comprehensive understanding of human behavior in all of its complexity. SBE-funded scientists study people and their behavior at scales ranging from cells to society and across space and time. They explore the mysteries of the brain—how it produces perception, action, cognition and language—and help make sense of the many political, social and economic challenges that confront communities, including energy use, migration, inequality, disaster response and warfare.

Ultimately, findings from the social, behavioral and economic sciences provide crucial insights into the self and society that strengthen the U.S. economy, improve health and well-being, enhance national security, and continue to position the nation as a leader of innovation and discovery.

Opposite page: The NSF-funded Center for Nanotechnology in Society at Arizona State University is dedicated to helping the public become a voice in nano and other emerging technologies. This helps scientists and engineers think deeply about where technologies are headed and how to make them work effectively for everyone; for example, when designing more liveable cities.

SBE DIVISIONS

Behavioral and Cognitive Sciences supports basic research in the psychological, linguistic, anthropological and geographic sciences to better understand how people interact at the biological, cultural and social levels, leading to new knowledge in everything from how the brain forms memories to how the use of resources changes the environment.

Social and Economic Sciences supports basic research in economic, social, political and organizational behavior that looks at everything from decision making to social capital development. Outcomes from this research provide insights into how social networks evolve, how cybercrime spreads and the optimal functioning of markets.

National Center for Science and Engineering Statistics is one of 13 principal federal statistical agencies and the nation's leading provider of statistical data on the U.S. science and engineering (S&E) enterprise.

Office of Multidisciplinary Activities supports interdisciplinary research and training in the social, behavioral and economic sciences, including SBE's intersections with other S&E fields.

DID YOU KNOW?

- An NSF-funded economist applied the principles of game theory to the problem of matching kidney recipients with donors, laying the groundwork for today's national kidney exchange program. To date, the program has saved more than 4,000 lives in the U.S.—a number that continues to grow.
- NSF has funded 55 Nobel Laureates in the economic sciences since 1969, including every U.S. winner since 1997.
- NSF-Funded researchers developed a computer-brain interface that allowed a patient with "locked-in syndrome" to vocalize sounds for the first time. This technology may also help others, such as veterans with severe paralysis.

IMPACTS

DETECTING READING PROBLEMS EARLY

Reading disabilities affect millions of Americans and can have long-term effects from childhood into adulthood. Dyslexia alone affects 5 to 10 percent of the U.S. population. An NSF-funded researcher has developed a tool that uses a child's brain waves to predict reading problems before they start. This is important because interventions for children are effective, but they need to start early. The researcher is now developing a diagnostic tool that can double or even triple the time window for implementing an intervention.

BETTER WARNING SYSTEMS, BETTER DISASTER RESPONSE

When a severe storm approaches, how a person responds can be a matter of life and death. Human response in the face of disaster greatly depends on how weather experts communicate the risks. NSF-funded scientists worked with the National Oceanic and Atmospheric Administration (NOAA) and their National Weather Service emergency responders to improve the communication of risks related to weather emergencies. For example, storm surge—rather than wind speed—is typically the deadliest and costliest force in a hurricane. Informed by NSF's research, NOAA now uses dynamic displays of storm surge presented visually to better communicate hurricane risks.

EYEWITNESS TESTIMONY THAT IS ROBUST AND RELIABLE

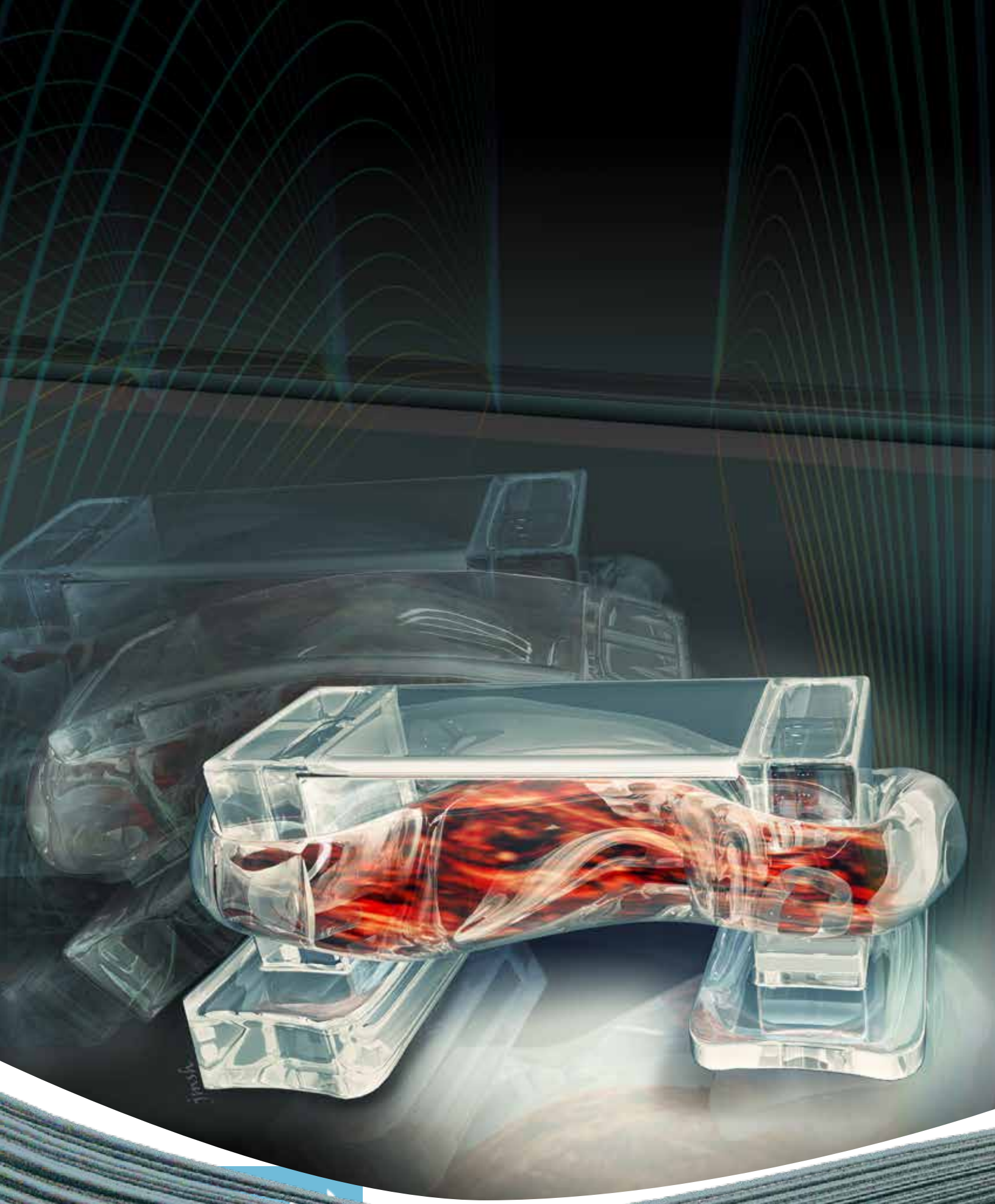
Crime investigators often rely on eyewitness testimony, yet misidentification is a primary cause of convictions of innocent people. NSF-supported scientists showed that changing how investigators conduct eyewitness procedures can reduce misidentification. Showing witnesses photos one at a time (not side by side) and telling them the suspect may not be pictured are ways to reduce false positives. Additionally, having an officer who is unaware of the suspect's identity conduct these procedures reduces misidentification as the officer is less likely to unintentionally convey information via tone of voice or posture. The research led many states to reevaluate their eyewitness procedures and the Department of Justice to adopt new guidelines.

BEHAVIORAL SCIENCE HELPS TRACK CRIMINALS, STOP CRIME

From hackers who steal identities to terrorists looking for new recruits, many criminals use the internet to achieve their goals. NSF-funded scientists have studied the way criminals organize and support each other's efforts and how they choose targets and implement plans. This research led to two major programs to stop crimes and arrest perpetrators. COPLINK is used by over 3,500 police agencies in the U.S. and in 25 NATO countries to trace criminal activity. CIA and FBI analysts use the Dark Web project to understand terrorism targets, recruitment activities and large-scale hacking efforts.

COUNTERING VIOLENT EXTREMISM

Why are extremist groups like ISIS so successful in recruiting new fighters? Many dismiss extremists as psychopaths or people seeking to achieve personal gain. Based on interviews with extremists in war zones, an NSF-funded researcher found the truth is more complicated. New recruits are often motivated by ethical and moral beliefs, suggesting that strategies designed to disrupt recruitment must include moral alternatives to violent extremism as much as material ones, such as access to economic opportunities. This research is informing efforts by the Department of Defense and other agencies to better counter violent extremism at home and abroad.



OFFICE OF INTEGRATIVE ACTIVITIES

INTRODUCTION

Basic discovery research often does not stay in a single lane; it frequently crosses disciplines. A physics researcher may need an engineer or a computer scientist to help test a theory or solve a problem. To address complex problems like this, NSF's Office of Integrative Activities (OIA) crosses boundaries to form unique partnerships between researchers and experts who need each other to carry out societally relevant initiatives.

OIA focuses on initiatives such as:

- NSF INCLUDES, an integrated, national initiative which develops STEM talent from all sectors and groups in society to help grow our economy.
- Science and Technology Centers (STCs), which conduct world-class research through partnerships among academic institutions, national laboratories, industrial organizations and others.
- Presidential Early Career Awards for Scientists and Engineers, which recognize scientists and engineers who show exceptional potential in the early stages of their independent research careers.

OIA's activities advance research excellence and innovation, develop human and infrastructure capacity critical to the U.S. S&E enterprise, and promote engagement of scientists and engineers at all career stages.

Opposite page: This artistic image represents tiny biological machines called "bio-bots." A fusion of biology and engineering, bio-bots are powered by skeletal muscle cells controlled by electrical impulses. This work was funded through a STC grant to the MIT, in collaboration with the University of Illinois, the Georgia Institute of Technology and other partner institutions.

OIA SECTIONS

Integrative Activities administers major interdisciplinary programs across the foundation and supports the NSF director's office through policy analysis and special projects that address NSF priorities.

Established Program to Stimulate Competitive Research (EPSCoR), which recently changed its name from "Experimental" to "Established," promotes sustainable increases in scientific research, education, training capacity and competitiveness in states and territories that have not historically benefited from federal research grants.

Evaluation and Assessment Capability provides centralized support and resources for data collection, analytics and the design of evaluation studies and surveys that enable NSF to more consistently evaluate the impacts of its investments, and to make more data-driven policy decisions.

DID YOU KNOW?

- Research Infrastructure Improvement awards were granted 313 times to date to stimulate sustainable R&D in EPSCoR jurisdictions.
- The 2004 Alan T. Waterman Award recipient, chemical and biological engineer Kristi Anseth, is designing new bioscaffolds, or temporary structures, upon which biological tissues can form to heal fractures, engineer new cartilage or even construct replacement heart valves.
- To date, NSF administered the selection of 506 recipients of the congressionally mandated National Medal of Science.

IMPACTS

UNDERWATER GPS CHANGES THE MAP

In Guam, researchers developed a new method for mapping underwater areas that is transforming how oceanographers observe the seafloor. Data from global positioning satellites are the primary method for mapping the Earth, but it's impossible for global positioning system (GPS) signals to pass through water, making detailed mapping of underwater features very difficult. By synchronizing underwater cameras with GPS buoys and using computer software to geo-tag—assign graphical location—photographs, NSF-funded researchers mapped for the first time all of Guam's Pago Bay and Apra Harbor.

NSF PROGRAM PROVIDES LIFT-OFF FOR STARTUPS

Administered through the Arkansas Economic Development Commission, NSF ESPCoR helped launch several startup companies in Arkansas, each tackling different challenges that impact everything from public health and manufacturing to energy use. One startup, WattGlass LLC, which developed a nanoparticle coating, produces antireflective coatings for solar panels that boost light absorption and increase electrical output by at least 8 percent. Another start-up, GeneCoMe Biotech LC, is addressing the alarming rise in multidrug-resistant bacteria by developing a plant-based alternative—cytokine—in place of the antibiotics currently injected into livestock to prevent disease.

BUILDING UP THE STEM WORKFORCE WITH A UNIQUE PAY STRATEGY

The STC for Emergent Behaviors of Integrated Cellular Systems (EBICS) increased the probability that local students from low socioeconomic backgrounds could earn a college education. EBICS expanded its Engaging New Generations at Georgia Tech through Engineering and Science program to MIT and other partner institutions. The program now pays high school students, most of whom are black from Title I schools, $10 an hour for their contributions to scientific research. The pay helps student families, while improving the quality of their college applications.

HAND-DISABILITY RESEARCH PROPELS INDUSTRY

No-pressure keyboards, widely-used in Apple products, were originally developed by a University of Delaware researcher with support from NSF's EPSCoR program. To help people with hand disabilities, he imagined a keyboard that required a softer touch. His innovation led to the startup company FingerWorks that created some of the world's first tablet computers with multi-touch technology. Apple acquired FingerWorks and the rest is history. As of August 2016, Apple has sold more than 1 billion iPhones and 308 million iPads equipped with touch keyboards.

WATERSHED IN UNDERSTANDING SEA LEVEL

The NSF-funded STC for Remote Sensing of Ice Sheets (CReSIS) developed image-gathering and data-retrieval technologies that vastly improve how we understand the physical features of the Antarctic and Greenland ice sheets. These ice sheets hold 99 percent of the world's fresh water in the form of ice. If they were to melt, they would cause enormous global sea-level rise. CReSIS' unique radar for ice sounding and imaging technology increased knowledge of how climate pressures might cause the ice sheets to behave. In fact, the technology produced 80 percent of the critical data used to make the new map of the Greenland Ice Sheet.

OFFICE OF INTERNATIONAL SCIENCE & ENGINEERING

INTRODUCTION

NSF's Office of International Science and Engineering (OISE) establishes and maintains strategic relationships with the Foundation's international peers. The Office funds U.S. scientists and engineers to pursue unique international research opportunities while providing research experiences for U.S. students to create a globally-engaged U.S. science and engineering workforce. For example:

- With Australia, a collaborative program is developing containers small enough to be injected directly into the bloodstream to deliver medicines.
- With South Korea, U.S. researchers are cooperating to create artificial muscles for use in soft robotics.
- With South Africa, students from the United States work with peers from the University of KwaZulu-Natal to improve water decontamination and provide basic sanitation to underserved populations.

The Office's specialized research programs prepare U.S. students to become members of the global STEM workforce. For example:

- Students from the University of Michigan conducted collaborative research with the South African National Space Agency to understand the impacts of solar disturbances on the Earth.
- Rice University's TerraNano program, a cooperative endeavor with Japan, provided undergraduates the opportunity to develop and study novel nanomaterials with electronic and vibrational properties in the terahertz range.

Opposite page: PIRE researches used three cameras set up on different towers to photograph individual tree crowns, discovering a pattern of leaf growth and death that helps us understand seasonality.

OISE CLUSTERS

Country and Regions establishes and maintains relationships with counterparts in foreign countries. In addition, the cluster is the primary interface with interagency partners who also focus on international relations (i.e. State Department, White House Office of Science and Technology Policy, etc).

Programs and Analysis develops, implements and monitors OISE programs. These programs seek to catalyze international science and develop a globally competitive U.S. scientific workforce. The cluster also develops foresight products for NSF leadership—a new capability expected to be fully operational in Fiscal Year 2018.

The **Administrative** cluster ensures consistent implementation of the Foundation's policies and procedures within the Office. The team ensures programmatic activities receive appropriate review, develops and implements the Office's budget, and assists Office leadership in human capital actions.

DID YOU KNOW?

- Permafrost regions occupy about 25 percent of the Northern Hemisphere and students from Tennessee and Russia are exploring 2-3 million-year-old permanently frozen sediments in the Kolyma lowland in Siberia to expand understanding of life at low temperatures.
- NSF-supported students gain international research experience in 37 countries and regions.
- NSF's Partnerships International Research and Education (PIRE) program supports high-quality research and education projects for U.S. researchers in 19 countries: U.S., Brazil, China, Czech Republic, France, Germany, India, Ireland, Italy, Japan, Korea, Mexico, Norway, Poland, Russia, Spain, Switzerland, Taiwan and Turkey.

IMPACTS

FOSSIL FIND REVEALS EARLY INTERCONTINENTAL MOVEMENT

A 21-million-year-old monkey fossil unearthed by NSF-funded researchers in Panama upended conventional thinking about when and how species moved from South America into North America. The researchers discovered the fossil, which is related to modern South American monkeys, on the North American landmass in rock strata exposed by the Panama Canal's expansion. While scientists long thought species moved northward via a 4-million-year-old land bridge—called the Isthmus of Panama—the fossil finding suggests species made the trek 17 million years earlier, before the bridge formed. NSF's PIRE program funded the once-in-a-century research opportunity.

RESEARCH SPURS GLOBAL, GEOHAZARD KNOWLEDGE INCREASE

An OISE-developed partnership is raising the Bangladesh government's awareness of potential natural hazard dangers there. Bangladesh, which is about the size of Iowa, with almost 170 million people, is vulnerable to huge earthquakes. To design stable, earthquake-resistant infrastructure, the partnership—composed of researchers from the U.S., Bangladesh, Germany, India and Italy—is working to understand Earth's structural features beneath Bangladesh. Data from the project drew the attention of the Bangladesh parliament and resulted in more than 15 peer reviewed papers in widely respected publications like *Nature Geoscience, Tectonophysics,* the *Journal of Geophysical Research* and others.

STUDENT TRAINEES SET TO REVOLUTIONIZE NANOFIBER MANUFACTURING

A novel method developed by student trainees could transform manufacturing of nanofibers for biomedicine, energy, filtration, high-rate fiber-production and more. Teams from the University of Alabama at Birmingham and the Czech Republic's Technical University of Liberec discovered that strong alternating electric fields produced on liquid polymers could be used to manufacture nanofibers much quicker and in more volume than current processes. The new process has an ability to generate continuous thread-like materials 100 nanometers or less in diameter at astonishing rates when compared to current fabrication processes.

PROTECTING CENTRAL AFRICA'S RAINFORESTS

The rainforests of Central Africa are tremendously important to the health of the planet. However, habitat loss occurs there at a rapid rate due to tree clearing, environmental change and growing human populations. This project, comprised of researchers and students from the U.S., Cameroon, Gabon, the United Kingdom, Germany, France and the Netherlands, is developing a framework for conserving Central African biodiversity. To help ease the effects of habitat loss and climate change, the researchers regularly meet with decision-makers to provide the latest scientific information on meaningful conservation measures.

ROLLS-ROYCE AND BOEING GET STUDENT ASSIST

More than 20 students from Virginia Tech and the University of Nottingham designed a replacement for the hydraulic and gear power transfer systems on the Rolls-Royce Trent 1000 turbofan engine. Working with Rolls-Royce in Derby, U.K., their design would replace the existing system with modern electronics, improving jet propulsion on Boeing Commercial Airplanes' 787 Dreamliner. Boeing purchases Trent 1000 engines from Rolls-Royce. The students are part of an OISE-led and supported—with additional funding from Boeing—international program that provides research experiences for students interested in future electric transportation systems.

RESOURCES AND SOCIAL MEDIA

National Science Foundation	nsf.gov
Directorate for Biological Sciences	nsf.gov/BIO
Directorate for Computer and Information Science and Engineering	nsf.gov/CISE
Directorate for Education and Human Resources	nsf.gov/EHR
Directorate for Engineering	nsf.gov/ENG
Directorate for Geosciences	nsf.gov/GEO
Directorate for Mathematical and Physical Sciences	nsf.gov/MPS
Directorate for Social, Behavioral, and Economic Sciences	nsf.gov/SBE
Office of Integrated Activities	nsf.gov/OIA
Office of International Science and Engineering	nsf.gov/OISE
Established Program to Stimulate Competitive Research	nsf.gov/EPSCoR
NSF and Congress Toolkit	nsf.gov/toolkit
Science360	science360.gov
Social Media	nsf.gov/social

IMAGE CREDITS

Cover: Nicolle Rager Fuller, NSF

Page i: NSF, Stephen Voss

Page ii: (top) Carnegie Institution of Washington; (bottom) NSF

Pages 2-3: Nicolle Rager Fuller, NSF

Page 4: The National Center for Optics and Photonics Education (OP-TEC)

Page 5: John C. Williams, Humanoid Engineering & Intelligent Robotics (HEIR) Lab, Marquette University

Pages 6: NSF

Page 7: (top row) ©iStock.com/tupungato; Sara Parks, NSF Iowa EPSCoR, Iowa State University; ©iStock.com/fatesun; (center row) Amanda Padbury, North Carolina State University College of Textiles; Amy Simmons, Padture Lab, Brown University; J.E. Doll, Michigan State University; (bottom row) Simulating eXtreme Spacetimes (SXS) project (http://www.black-holes.org); from *ATE Centers Impact 2016-2017* (www.atecenters.org); superjoseph/Shutterstock.com

Pages 8-10: Nicolle Rager Fuller, NSF

Page 14: Alessandro Catenazzi, Southern Illinois University Carbondale

Page 16: (top) ©iStock.com/Sage78; John Angell, UMass Boston; (center) Steve Byland/Shutterstock.com; (bottom) Abraham Karam, NEON, Inc.; David Gruber, Baruch College, City University of New York

Page 17: (top to bottom) Arable Labs, Inc.; University of Pittsburgh Medical Center/Pitt Health Sciences; Jennifer Doudna, University of California, Berkeley; T. Noges; Deisseroth Lab

Page 18: Douglas Pancoast and Satya Mark Basu, School of the Art Institute of Chicago/Array of Things

Page 20: (top) Computer Science and Engineering Division of Electrical Engineering and the Computer Science Department, University of Michigan; Nicolle Rager Fuller, NSF; (bottom) Andrew Kelly, NY Hall of Science; Texas Advanced Computing Center

Page 21: (top to bottom) pixelrain/Shutterstock.com; Daphne Koller; Douglas Pancoast & Satya Mark Basu, School of the Art Institute of Chicago/Array of Things; (c)iStock.com/KrulUA; Personal Robots Group, MIT Media Lab

Page 22: Ocean Discovery Institute

Page 24: (top) Kristian Dzilenski; Science Museum of Minnesota; (bottom) from *ATE Centers Impact 2016-2017* (www.atecenters.org); Rob Margetta, NSF

Page 25: (top to bottom) ASSISTments; ©iStock.com/Ridofranz; Marco Hatch, Western Washington University; Aisha Hassan, Queens College, CUNY; Georgia Computes! Georgia Tech

Page 26: Nano/Micro Photonics Laboratory, Electrical and Systems Engineering Department, Washington University, Saint Louis

Page 28: (top) Craig Chandler, University Communications, University of Nebraska-Lincoln; Michael Shafer; (center) Paul Prucnal, Department of Electrical Engineering, Princeton University; Shayan Mookherjea, University of California, San Diego; (bottom) Eve Syrkin Wurtele, William Schneller, Paul Klippel, Greg Hanes, Andrew Navratil and Diane Bassham, Iowa State University; Altaeros Energies

Page 29: (top to bottom) ©iStock.com/bbraley; Miromatrix Medical; ©iStock.com/Henrik5000; ©iStock.com/roberthyrons; Second Sight Medical Products

Page 30: ©iStock.com/Jacques van Dinteren

Page 32: (top) Jacob DeFlitch; Jeffrey Johnson, Department of Geosciences, Boise State University; (bottom) Jennifer Smith, Scripps Institution of Oceanography; Keith Vanderlinde, NSF

Page 33: (top to bottom) Tim Garrett, University of Utah; ©iStock.com/Chalabala; Ian Kluft, CC BY-SA 3.0; Ruth Schulte, USGS; ©iStock.com/johnandersonphoto

Page 34: Stefano Sacanna, New York University

Page 36: (top) Gemini Observatory/AURA; Andrey Vilesov, Chemistry Department, University of Southern California, Los Angeles; (center) Pupa U.P.A. Gilbert and Christopher E. Killian; Richard Palais and Luc Benard, University of California, Irvine; (bottom) LIGO/T. Pyle; ThinkStock

Page 37: (top to bottom) ©iStock.com/Maxiphoto; ©iStock.com/cosmin4000; NSF; © iStock.com/Pitju; John W. Harvey, National Solar Observatory

Page 38: The Center for Nanotechnology in Society at Arizona State University

Page 40: (top) ©iStock.com/FatCamera; Thinkstock; (bottom) Mmaxer/Shutterstock.com; ©iStock.com/shironosov

Page 41: (top to bottom) Sarah Laszlo, Brain and Machine Laboratory, Binghamton University; Ning Lin, Princeton University; Photographee.eu/Shutterstock.com; Jupiter Images; U.S. Army

Page 42: Janet Sinn-Hanlon, DesignGroup@VetMed for Dr. Rashid Bashir, Department of Bioengineering, University of Illinois

Page 44: (top to bottom) ©iStock.com/Pinkypills; University of Maine; ©iStock.com/Ridofranz

Page 45: (top to bottom) Jason S. Biggs, University of Guam Marine Laboratory; Thinnapob Proongsak/Shutterstock.com; ©iStock.com/asiseeit; ©iStock.com/Anatoliy Babiy; Bruce Vaughn, INSTAAR, University of Colorado

Page 46: Aline Lopes, National Institute of Amazon Research, Manaus

Page 48: (top to bottom) Central African Biodiversity Alliance; Alia Khan, University of Colorado Boulder; ©iStock.com/CreativaImages

Page 49: (top to bottom) Jason Head, University of Cambridge; eGuide Travel, CC BY 2.0; Douglas Pecot, Department of Materials Science and Engineering at the University of Alabama, Birmingham; jbdodane, CC BY-NC 2.0; Dentonyoder, CC BY-SA 4.0

Written by: Susan Reiss, NSF; Kathleen Garrigan, NSF; Bobbie Mixon, NSF; Dana Hunter, NSF; Brittany Quade, NSF; Denise Zaninno, NSF
Design by: Adrian Apodaca, NSF
Illustrations by: Nicolle Rager Fuller, NSF
Image research by: Marnie Briggs, NSF; Anne Du Vivier, NSF


www.nsf.gov
National Science Foundation | 4201 Wilson Blvd. | Arlington, VA 22230
wissenschaft
sayansi
sciencia
videnskab
科学
NSF 17-800