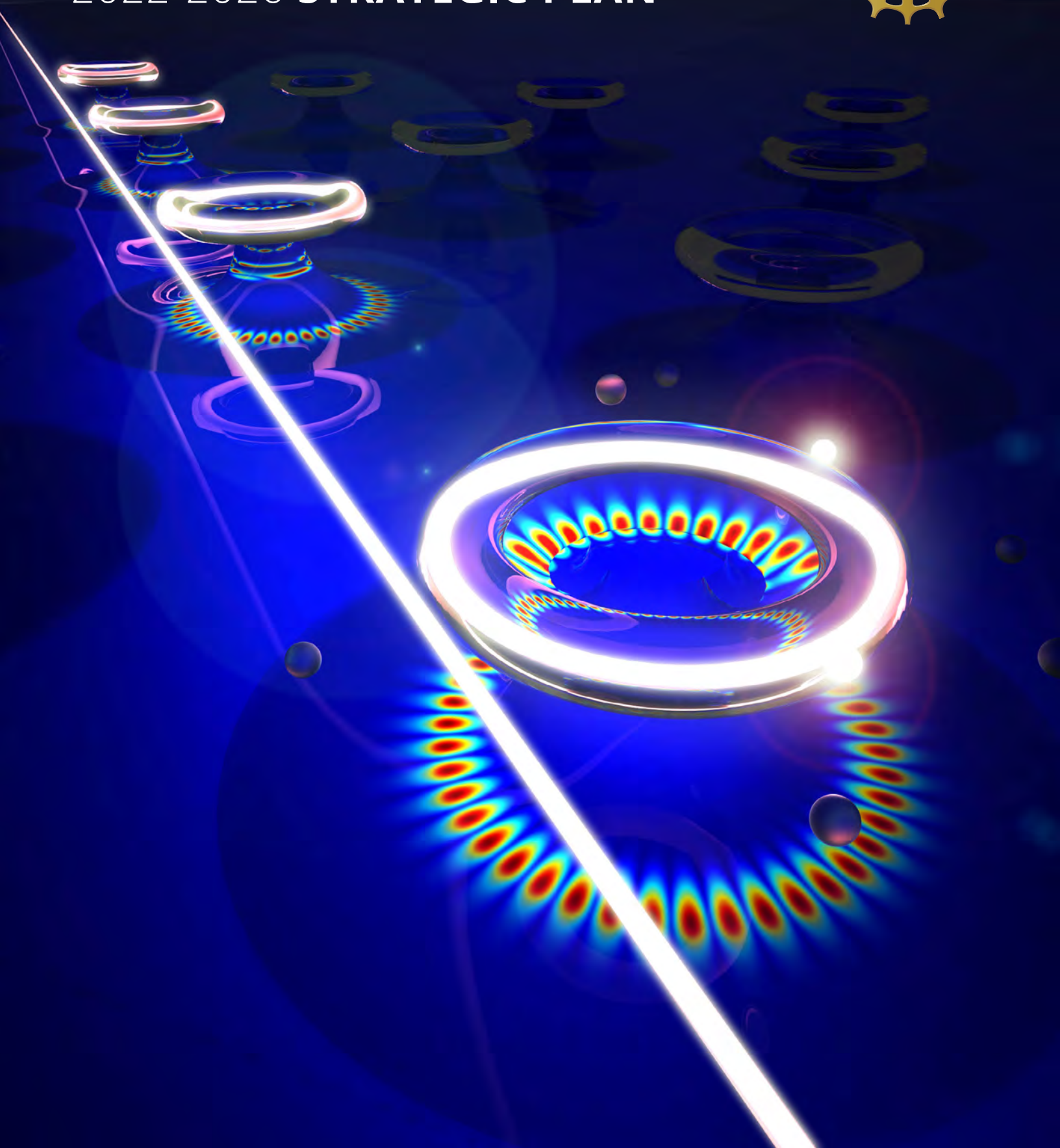
U.S. NATIONAL SCIENCE FOUNDATION

2022-2026 **STRATEGIC PLAN**



The "Government Performance and Results Act" (GPRA) (Public Law 103-62) and the "GPRA Modernization Act of 2010" (Public Law 111-352) require federal agencies to develop strategic plans setting forth long-term goals and objectives. Guidance on the development of agency strategic plans is included in the Office of Management and Budget Circular A-11. These plans form part of the federal performance framework. "Leading the World in Discovery and Innovation, STEM Talent Development, and the Delivery of Benefits from Research" updates and replaces "Building the Future: Investing in Discovery and Innovation, NSF Strategic Plan for Fiscal Years (FY) 2018-2022" (NSF 18-045). It has been prepared by NSF staff, working with the National Science Board, with input from the science, engineering and education research communities, industry and others.

About the cover: Representation of a "Whispering Gallery" mode resonator detecting single nanoparticles.
Credit: Nano/Micro Photonics Laboratory, Electrical and Systems Engineering Department, Washington University, St. Louis.

MESSAGE FROM THE NSF DIRECTOR

Strategic investments by the U.S. National Science Foundation are advancing many industries, tools and products that are fueling economic growth and creating good-paying jobs throughout the nation and around the world. Today, more than ever, we are seeing how the power of NSF investments in science and technology are making deep and meaningful impacts on lives and communities. From nanotechnology and the internet to additive manufacturing, smartphone technologies and companies like Qualcomm and Google, NSF investments create jobs, grow new regional engines of economic development and innovation and improve the lives of billions of people.

This "2022-2026 Strategic Plan" builds on 70 years of NSF driving critical research across all fields of S&E and lays out our vision for the future of discovery and innovation. NSF's four strategic goals – empower, discover, impact and excel – will serve as a foundation for ensuring NSF and the nation remain at the forefront of scientific discovery and technological advancements that change the world.

Today, our society is surrounded by tremendous challenges, and each one is an opportunity that science can address. Climate change, disaster resilience, equity for all – these are just some of the real-world problems that need to be solved. The past two years have dramatically underscored the importance of how fundamental research can be coupled with use-inspired innovations to meet such challenges. And the world will continue to turn to the S&E community for answers.

Because NSF supports the full spectrum of fundamental research, from curiosity-driven to use-inspired, we can foster the unique, cross-cutting discovery and innovation that is so critical to our nation's long-term competitiveness. Our investments will continue to expand our strategic leadership across emerging areas such as artificial intelligence, quantum information science, next-generation wireless networking, biotechnology and advanced computing.

For example, the new Technology, Innovation, and Partnerships (TIP) Directorate will enable NSF to focus cross-disciplinary expertise and foster cross-sector partnerships to develop solutions at speed and scale. TIP will build on successful innovation programs such as the NSF Convergence Accelerator, as well as our world-leading Lab-to-Market Platform, spanning the NSF Innovation Corps, Partnerships for Innovation, Small Business Innovation Research and Small Business Technology Transfer programs.

We need groundbreaking discoveries to address grand challenges that continue to shape our lives and these discoveries and breakthroughs will not be possible without the full power of bright and talented discoverers from every part of the nation. While NSF has long invested in efforts to broaden participation in STEM, it is more important now than ever to underscore that the inclusion of all people in STEM is vital to the nation's health, security and global leadership. We need young inspiring scientists from every background to be part of a STEM community full of diverse perspectives that can drive the research enterprise to new breakthroughs and innovations and help solve our most pressing challenges.

With the support of Congress, the administration and the American people, NSF remains at the forefront of science, engineering and technology. We provide pathways to success for STEM talent to develop the workforce of the future. We construct facilities needed to support the widest range of science and technology advancements. And we bring together partners from institutions, agencies and industries to advance the frontiers of research. This enables us to continue transforming the world for the benefit of all.

Sethuraman Panchanathan
Director, National Science Foundation

Leading the World in Discovery and Innovation, STEM Talent Development and the Delivery of Benefits from Research

NSF Strategic Plan for Fiscal Years 2022-2026

National Science Foundation

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"There is nothing which can better deserve your patronage than the promotion of Science and Literature. Knowledge is in every country the surest basis of public happiness."

- George Washington, First Annual Message to Congress on the State of the Union (1790).

Overview

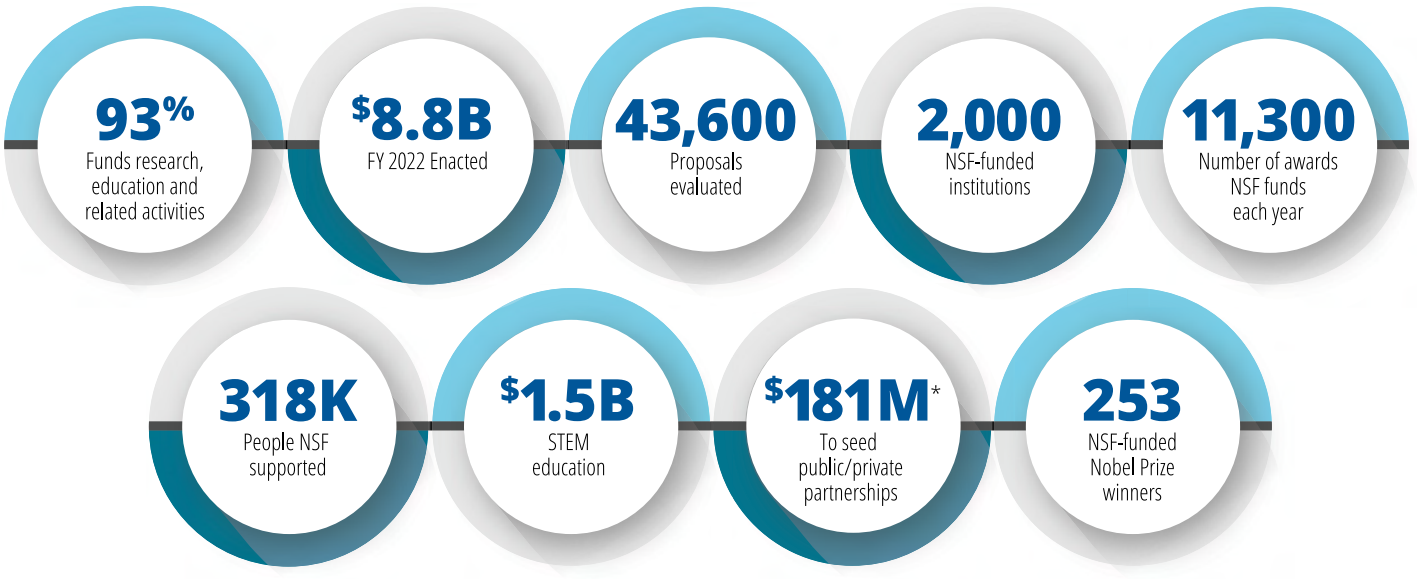
NSF's Mission: To promote the progress of science to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes.

NSF ***promotes the progress of science*** by investing in research to expand knowledge in science, engineering and education. NSF also invests in actions that increase the capacity of the U.S. to conduct and exploit such research.

NSF ***advances the national health, prosperity, and welfare*** through the contributions that NSF-funded research makes. For example, NSF research has made possible many of the technological advances that have improved medicine, communications, transportation, manufacturing and the utilization of natural resources, together with a broad range of other impacts on our lives.

NSF's contributions to ***securing the national defense*** includes research in cryptography, cybersecurity, novel materials, advanced analytics for massive datasets, artificial intelligence, environmental change, quantum information systems and advanced manufacturing, to name just a few.

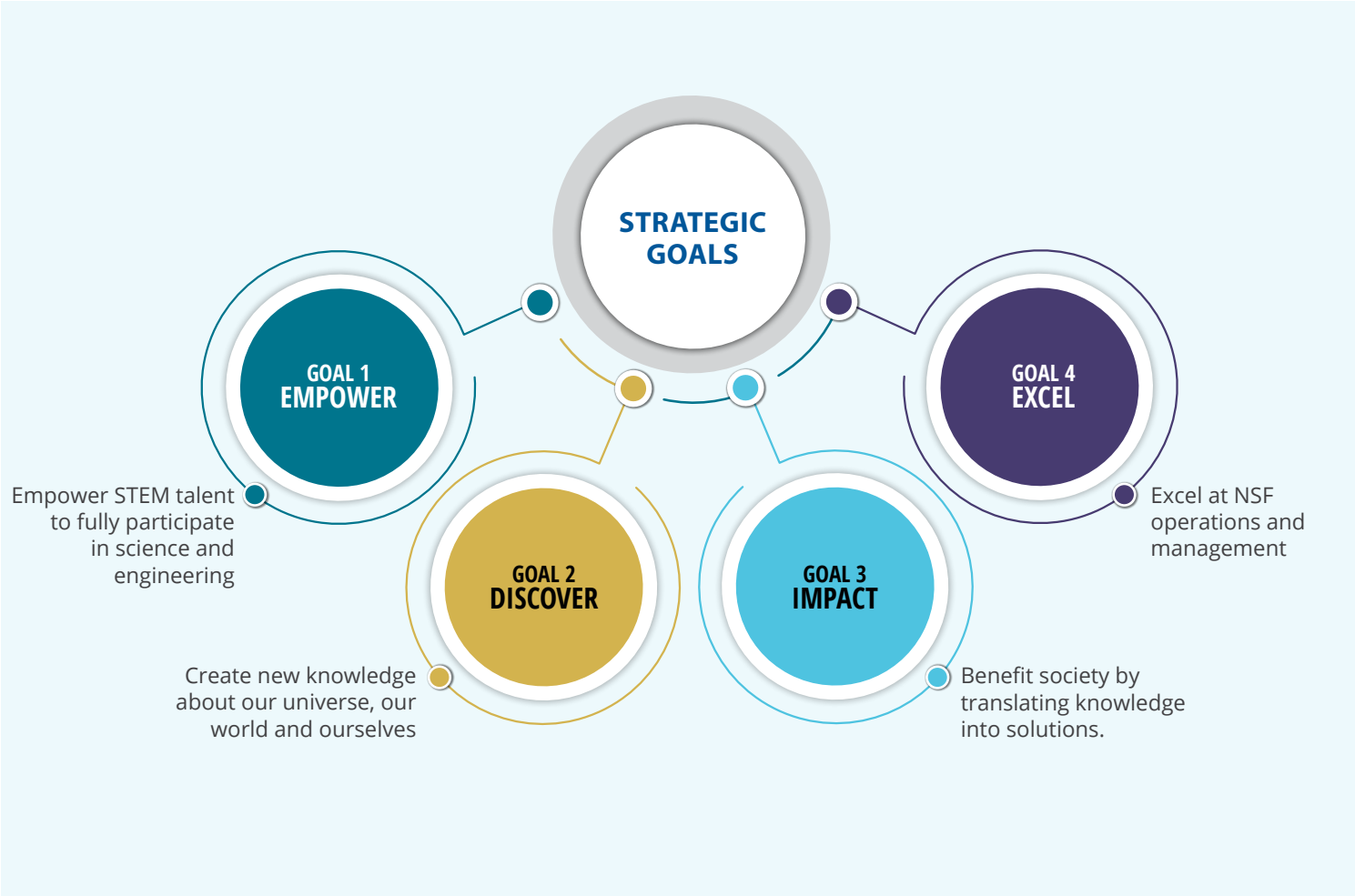
The U.S. National Science Foundation advances the frontiers of research; creates pathways to success for students and researchers; provides research infrastructure and instruments to enable discovery; and encourages learning everywhere. Since NSF's inception in 1950, the 2,000 person agency has invested in cutting-edge research and talented people who explore the unknown, seek to demystify nature and expand the understanding of science and engineering. NSF is committed to making science accessible and deepening the understanding of science by all Americans.



Data represents FY 2021 Actuals unless otherwise indicated.
**Corresponds to NSF investments initiated in FY 2021 and spanning multiple years.*

NSF's strategic plan aligns with national priorities such as pandemic response, economic recovery, racial equity, and addressing climate change. It advances the roadmap laid out in the NSB *Vision 2030* report, delivering the benefits from research, developing STEM talent, expanding the geography of innovation, and leading globally by cultivating a global science and engineering community based on shared values and strategic cooperation.

To accomplish all of this, NSF is focusing on people as the heart of the research enterprise. Investments in people are the key to strengthening the Science & Engineering community. **NSF pursues the following four strategic goals:**



VISION

A nation that leads the world in science and engineering research and innovation, to the benefit of all, without barriers to participation.

MISSION

To promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes.

CORE VALUES

NSF's strength is scientific leadership. We value diversity and inclusion, demonstrate integrity and excellence in our devotion to public service, and prioritize innovation and collaboration in our support of the work of the scientific community and of each other.

Stakeholder Engagement

Stakeholders took as their starting point the key elements of the NSF 2018-2022 Strategic Plan and provided comments and suggestions to inform the new plan. In addition to comments from individuals and organizations received through an online portal, agency officials held discussions with stakeholder groups, including the National Science Board, numerous advisory committees, academic organizations, professional societies and NSF staff.

The NSF Vision: A nation that leads the world in science and engineering research and innovation, to the benefit of all, without barriers to participation.

Never have science and technology been more important to the nation. Society is confronted by a growing set of challenges that call for the insights that science and engineering can provide. Advances in how we learn, work, collaborate and explore are creating opportunities to greatly increase the rate of discovery and broaden participation in S&E. An increasingly diverse global research community is enriching the breadth of questions that can be asked and answered. To both seize these opportunities and address these challenges, **NSF will pursue a vision built on three pillars:**

Advancing the frontiers of research and innovation

Ensuring accessibility and inclusivity

Being a leader in the global S&E enterprise

These pillars rest on a foundation of people, ideas, partnerships and the translation of fundamental research into benefits for society. Our vision emphasizes the importance of interweaving innovation in everything we do. It will enable NSF to strengthen at speed and scale the delivery of its mission to the American people.

For NSF to achieve this vision, requires not only advancing the frontiers of science, engineering and education, but also ensuring that U.S. research is an inclusive enterprise that harnesses the talent of all sectors of American society – a research enterprise that incorporates the rich demographic and geographic diversity of the nation.

In the pages that follow, we show how this vision aligns with NSF's mission, national priorities and the National Science Board's *Vision 2030* report. We describe the strategic goals, objectives and core strategies that will enable NSF to harness the fruits of research for the prosperity and well-being of its citizens. And we lay out a compelling vision for investments in discoveries, discoverers, impacts and excellence.

The NSF Mission: To promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes.

The U.S. National Science Foundation (NSF) is an independent federal agency that supports research at the frontiers of current knowledge, across all fields of science, engineering and education. It was established by the NSF Act of 1950 (Public Law 81-507). NSF adopted the purpose of that Act as its mission: *to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense.* This has guided NSF's activities ever since.

NSF *promotes the progress of science* by investing in research to expand knowledge in science, engineering and education, and by investing in actions that increase the capacity of the Nation to conduct and exploit such research.

NSF *advances the national health, prosperity and welfare* through the contributions that NSF-funded research makes to the well-being of the Nation. NSF research has made possible many of the technological advances that have improved health, communications, transportation, manufacturing and the utilization of natural resources. During 2020, NSF supported research to understand how the SARS-CoV-2 virus mutates, to learn more about the virus's biology and to explore ways of mitigating its impact.

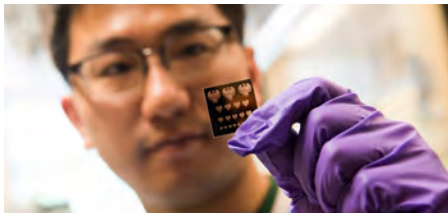
NSF's contributions to *securing the national defense* include research in cryptography, cybersecurity, novel materials, advanced analytics for massive datasets, artificial intelligence, environmental change, quantum information systems and advanced manufacturing, to name but a few.

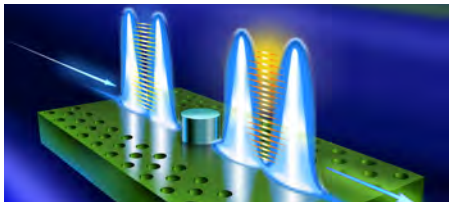
NSF's mission is to enable society to discover more about the world and universe that we all inhabit, to point the way to solutions to the challenges that confront us and to reveal opportunities to translate new knowledge into improvements in well-being, including strengthening the U.S. economy by making new technologies possible. By understanding how the world works, how people learn, and how to make new things, we make possible advances in everything from manufacturing and education to food production and health.

Given its mission to advance all fields of S&E, NSF was uniquely positioned to have a massive impact on our country's responsiveness to the COVID-19 pandemic. NSF-funded researchers rapidly mobilized to provide insights into the pandemic and how to mitigate it.

In 2020, NSF celebrated its 70th anniversary. Now is the time to refresh and reinvigorate our strategy for fulfilling NSF's mission. In the years ahead, NSF must work to strengthen the research enterprise at speed and scale -- to make new discoveries and to generate and mobilize new knowledge at a pace that will enable society to address the pressing challenges that confront it.

Now is the time to refresh and reinvigorate our strategy for fulfilling our mission. In the years ahead, NSF must work to strengthen the research enterprise at speed and scale.





Hyena: Credit: Claire Sanderson
Yuanyuan Wang holds a "mask" used in a process making it easier to build nanomaterials into transistors, solar cells and other devices. Credit: Photo courtesy of The University of Chicago/Jean Lachat
Quantum logic gate takes advantage of new form of light: Credit: Jung-Tsung Shen, Preston M. Green Department of Electrical & Systems Engineering, Washington University in St. Louis

BACKGROUND

With an annual budget of about $8.8 billion (Fiscal Year 2022), NSF's investments in people, ideas and solutions drive progress in every field of S&E. By supporting bold, large-scale research with meaningful societal impact, NSF keeps the U.S. on the leading edge of discovery and innovation.

NSF allocates **94%** of its budget to research projects, facilities and STEM education. NSF funds research in all states and U.S. territories - reaching **2,000** academic and other private and public institutions. In fact, NSF supports **24%** of all federally funded research at academic institutions. On average, NSF receives approximately **43,000** grant proposals annually and funds about **12,000**. NSF also supports innovation by small businesses, partnerships among academia, industry and national laboratories and research in non-profit non-academic organizations.

NSF is a unique federal agency. It advances research, infrastructure and people across all science and technology disciplines; any topic can come in the door. And it is able to support the best ideas in and across all fields. This bottom-up approach fosters creativity from the nation's brightest minds and enables NSF to tap into the full diversity of people, ideas and communities throughout the United States.

NSF advances innovation, researches more effective approaches to teaching, provides entrepreneurship training to academic researchers and fosters partnerships between academia, industry, nonprofit entities and government. It invests in ideas with high technological risk and the potential for significant benefits. And it stimulates and supports international research collaboration.

NSF's investments in discovery and innovation provide the basis for new technologies and create a wealth of broader impacts for the U.S. Investments in projects, people and infrastructure have led to discoveries that have stimulated economic growth, improved the quality of life for many Americans and deepened the understanding of the universe around us. NSF fosters curiosity-driven, exploratory, use-inspired and solutions-focused research that transforms our lives.

NSF funds programs designed to foster the development of the high-quality, diverse workforce needed to carry out the Nation's Science, Technology, Engineering and Mathematics (STEM) research and to build capacity for undergraduate, graduate and postdoctoral research training.

NSF supports training in research integrity and the ethical conduct of research, the dissemination of the results of NSF-funded research and infrastructure to provide access to the data generated. In promoting the responsible and ethical conduct of research, it also enhances research security.

NSF supports an advanced research infrastructure that includes oceanographic and atmospheric research platforms, astronomical observatories, particle accelerators, seismic observatories, U.S. research stations in Antarctica, advanced cyberinfrastructure, sustained large-scale surveys and more.

Each year, NSF receives tens of thousands of competitive requests for funding, which it evaluates using a rigorous merit review process. NSF's merit review uses two primary criteria to evaluate proposals for new activities – intellectual merit (meaning the potential to advance knowledge) and the project's broader impacts (encompassing the potential to benefit society and contribute to achieving specific desired societal outcomes).

NSF funding reaches all 50 states. In FY 2019, over 300,000 people, including students, postdoctoral fellows, researchers, trainees and teachers, were supported by NSF awards. At least 248 Nobel Prize winners received support from NSF at some point in their careers.

NSF's investments will fuel our economy for decades to come, produce high-paying jobs for American workers, improve American prosperity and quality of life and enhance national security.

The nature of NSF-supported research and innovation

NSF supports a broad spectrum of research and innovation. This goes far beyond the popular notion of a white-coated scientist who works at a lab bench and publishes scholarly articles in learned journals. The fundamental source of new knowledge is curiosity. Sometimes this involves asking the questions "what?" and "why?" that are motivated by a desire to understand. Often, the curiosity is focused on exploring innovative solutions to problems that challenge society.

NSF supports research that spans a continuum from exploratory to use-inspired in which insights in exploratory research prompt advances in solutions-focused research and new questions surfaced by use-inspired research generate new directions for exploration. It also focuses on diversifying the research enterprise. The benefits of diversity for creative activities such as research and innovation are well documented.[1] The more people engage in research and the more diverse their backgrounds, the richer the range of questions asked. The result is a greater breadth of discovery and more creative solutions to societal challenges.

Innovation – the creation and delivery of knowledge, products or services with lasting societal benefits – is woven throughout the fabric of NSF. Partnerships are a key tool for accelerating the speed of progress and the scale of its impact. NSF supports innovation through its funding of fundamental research and programs that foster the translation of scientific discoveries into new products or services. NSF programs for entrepreneurship training and research partnerships between universities, industry, high-tech startups, nonprofits and small businesses support the technologies of tomorrow and speed new ideas from the lab, computer or notepad to the marketplace. NSF also innovates by continually improving its processes for identifying and supporting the discoverers and discoveries that are the key to remaining at the forefront of science and technology.

Differently shaped gold nanoparticles: Credit: Nkauj Vang, University of Minnesota

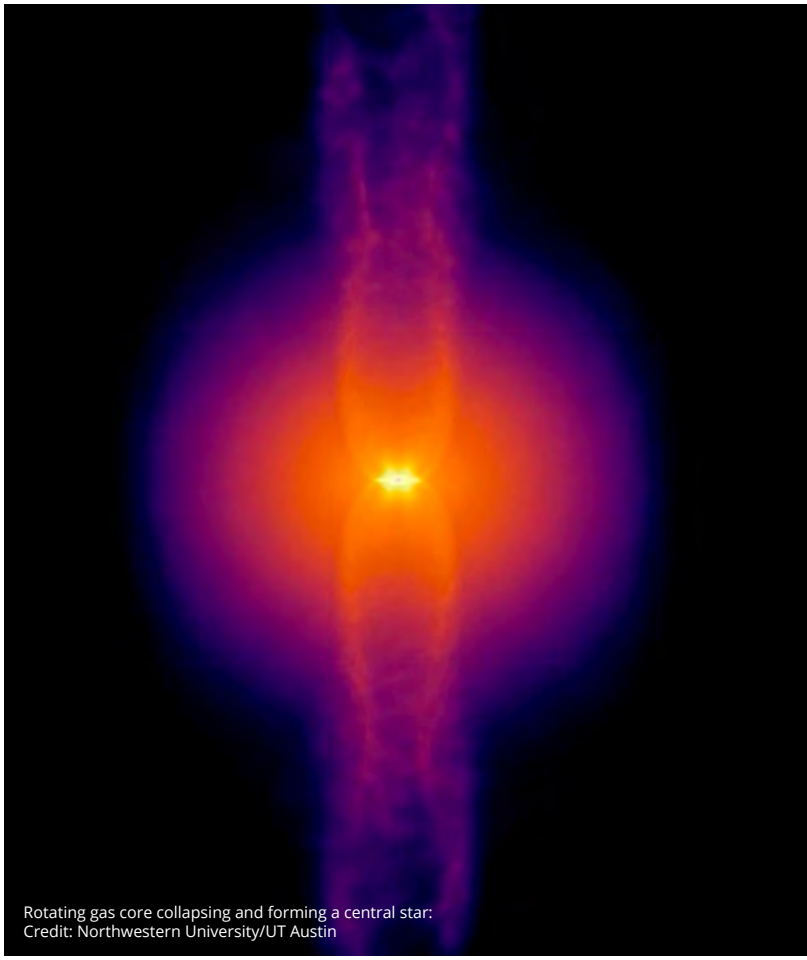
[1] For example, "Making gender diversity work for scientific discovery and innovation." Nature Hum. Behav. 2, 726-734, (2018) and "Diversity Makes Better Science." Association of Psychological Science Observer, 25(5), (2012).

The nature of NSF-supported research and innovation (continued)

NSF's support for research and innovation is essential for the well-being of America and for the nation's continued global leadership: "Fundamental research is fundamentally different than any other kind of investment. … it is a remarkable thing: because time and time again, we've found that basic research can pay huge, out-of-proportion returns. Basic research can completely transform for the better our society, our economy, our defense." [2]

Congress has emphasized that, "Scientific and technological advancement have been the largest drivers of economic growth in the last 50 years, with the Federal Government being the largest investor in basic research."[3] To realize these benefits for society, NSF makes strategic investments in basic research, advancing technology, the STEM workforce and research infrastructure. These investments enhance the nation's global competitiveness economically and scientifically. They are vital for advancing the frontiers of research, ensuring accessibility and inclusivity and securing global leadership. They also help the nation meet immediate needs such as combating COVID-19 and building resilience to future pandemics, addressing climate change, advancing equity and promoting economic recovery.

NSF's investments in academic research play a vital role. As researchers have shown, "when universities have greater commercial engagement, they tend to create technologies that consolidate the status quo, but when they receive more federal funding for academic research, they tend to produce more destabilizing inventions." [4] This is also recognized by industry: "[T]he functions served by industrial R&D and government R&D are fairly different. Industrial R&D is generally more geared toward applied research and development, which tends to be shorter-term, more incremental and results in private benefits. In contrast, public sector R&D is oriented around basic research – fundamental knowledge that underlies innovation – which tends to be higher risk, longer-term and has much broader and far-reaching societal benefits. This is especially true of non-defense U.S. research agencies including NSF…" [5]



Rotating gas core collapsing and forming a central star: Credit: Northwestern University/UT Austin

As other countries rapidly advance the education and training of their citizens in science and engineering, deploy highly capable research infrastructure and increase the resources devoted to research, NSF's mission becomes ever more critical. If the U.S. is to remain competitive in a world where economic and security advances are increasingly based on sophisticated technologies, made possible by a deep scientific and engineering understanding, then NSF must continue to invest in a world-class research enterprise, support the development of a globally competitive scientific and engineering workforce and foster greater understanding of science and technology among the American public.

[2] Lander (2015), "The Miracle Machine." Address to the National Math Festival. Available at, https://www.msri.org/system/cms/files/132/files/original/Lander-Case_for_Research.pdf.
[3] From Pub. L. 114-329, title II, §201(b)(1), 2016.
[4] Funk and Owen-Smith (2017), A Dynamic Network Measure of Technological Change. Management Science, vol. 63, no. 3, pp. 791–817.
[5] Benchmarks 2019. A Report by the Task Force on American Innovation. http://www.innovationtaskforce.org/wp-content/uploads/2019/05/Benchmarks-2019-SPA-Final4.pdf.

IV CORE VALUES

NSF's core values are essential and enduring tenets that guide everyone in the organization as we support the agency's mission. They have been developed with the active engagement of NSF staff. These values identify who we are and what is important to us. They guide how we make decisions, set priorities, address challenges, manage trade-offs, recruit and develop personnel and work together with our awardees.

NSF's strength is **scientific leadership**. We value **diversity and inclusion**, demonstrate **integrity and excellence** in our devotion to **public service** and prioritize **innovation and collaboration** in our support of the work of the scientific community and of each other.

NSF's Core Values	
Scientific Leadership	We support the expansion of the frontiers of knowledge and the integration of that knowledge into industry and education.
Diversity and Inclusion	We value the knowledge, skills, abilities, experiences and perspectives that colleagues from different backgrounds bring to our work and workplace. We recognize that these things strengthen NSF's ability to fulfill its mission. We strive to maintain a staff that is representative of the broader national community. We support outstanding researchers and innovative thinkers from across our nation's diversity of regions, organizations and demographic groups.
Integrity and Excellence	We hold each other and our awardees to the highest standards of ethical behavior. We strive to ensure the trustworthiness of the results of NSF-funded research. We ensure decisions are fairly made and communicated respectfully. We maintain the highest standards in merit review, financial management, award administration and business operations. We use rigorous review by experts to ensure that only the best ideas are funded. We apply new and creative ideas to improve our processes and our impact.
Public Service	We proudly value our role as public servants who enable the research community to identify new paths for expanding knowledge and addressing societal challenges.
Innovation and Collaboration	We apply new and creative ideas to improve our processes and our impact. We work in a collaborative enterprise where teamwork is essential. We value the perspectives and values of our colleagues, recognize that combining our knowledge enables us to find more robust solutions and acknowledge the contributions that we each make to our shared success; we are committed to listening, communicating effectively and working collegially. We share both ideas and responsibilities with colleagues in pursuit of common goals.

A Case For Urgency

NSF's role in supporting research and innovation has never been more important, and the opportunities to create lasting benefits are immense. Around the world, societies are transitioning to more knowledge-based economies. Global observations of the natural and human environments are revealing the growing footprint of human society. Advances in science and engineering are making possible new technologies that accelerate opportunities for discovery and change our interactions with each other. The growth of opportunities for collaboration, learning, commerce and research in the digital realm of cyberspace has characterized the first two decades of the 21st century. Convergence research, in which many types of scientists and engineers come together to bring a combined array of perspectives and techniques to bear on very challenging research questions with potentially high payoffs, is a potent force.

At the same time, the emergence of zoonotic diseases, the impact of environmental change on agriculture and infrastructure, the prevalence of megafires, changes in marine ecosystems and the ubiquity of plastic waste, from mountain tops to ocean depths, underline the importance of scientific understanding for health, prosperity and welfare.

Developments such as these highlight the importance of continually investing in fundamental research in science, engineering and learning and of ensuring the advances in understanding produced by research are integrated into education and society.

NSF's strategic plan recognizes that the landscape of research is rapidly evolving. Here we list some of the key contextual factors that shape NSF's strategic planning and investments.

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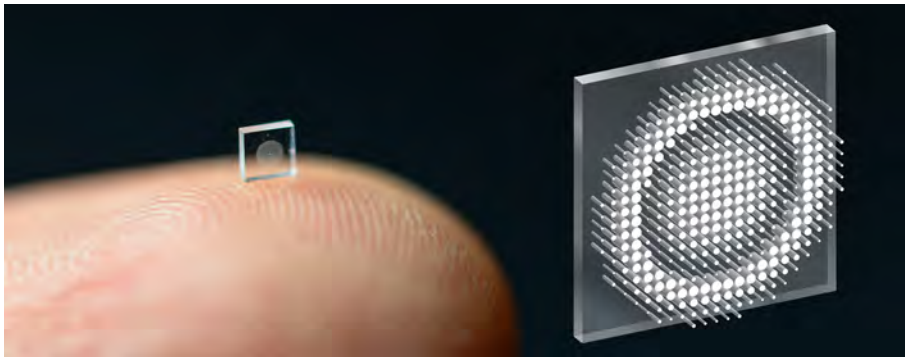


Sunflowers increase foraging habitats for bees: Credit: Courtesy Ben Barnhart
Ultracompact camera: Princeton Computational Imaging Lab

Contextual Factors

Global Engagement

S&E research is a worldwide enterprise. The value to society of the fruits of basic research is recognized around the world. As a result, we see countries such as China, India and others increasing their investments in fundamental research and deploying them strategically to encourage greater risk-taking in the exploration of new ideas and to help society meet looming challenges. Humanity's collective knowledge is growing rapidly. With that growth come opportunities for new international collaborations that tackle some of the thorniest problems that confront the global community. International exchanges of STEM talent between countries becomes ever more important to progress.

To capitalize on scientific and technological advances, the U.S. needs to prepare workforces with the skills to take advantage of the opportunities these advances present. NSF's research into how people learn, into the effectiveness of new learning technologies that are available in an increasingly digital and networked world, and into how learning can continue throughout a person's lifetime is crucial if we are to exploit these opportunities and maintain a competitive economy.

To compete globally, we must collaborate globally. Many of the great scientific challenges of our time, such as climate change and the degradation of environmental services, are global in scale and require research into global solutions. Pioneering observations in physics and astronomy increasingly require complex infrastructure designed and implemented by teams of hundreds or thousands of experts from around the world. As major achievements from the space program to the information technology revolution have demonstrated, the impact of domestic talent is magnified when we also attract foreign talent to our research enterprise.

Accelerating Impact

We are learning that strengthening the speed and scale of research and the application of its results to deliver benefits to society is something that can be accelerated through strategic thinking. From industry, the example of the technology accelerator[6] informs new approaches to fostering partnerships that provide agile mechanisms to translate the results of use-inspired basic research into practice. The infusion of training in entrepreneurship into undergraduate and graduate experiences can speed the translation of new discoveries into commercial and public policy applications. Modern scientific and technological workplaces increasingly rely on teams of individuals with the skills needed to work effectively and creatively in groups. Examples such as these illustrate the potential benefits of transforming our approaches to graduate and undergraduate training.[7] NSF supports research to understand what approaches will work and catalyzes their adoption by U.S. colleges and universities.

Star trails over the Mayall Telescope at Kitt Peak: Credit: P. Marenfeld; NOIRLab/NSF/AURA (Available under Creative Commons Attribution 4.0 International)

[6]See, for example, https://hbr.org/2016/03/what-startup-accelerators-really-do and https://www.economist.com/briefing/2020/04/11/the-changes-covid-19-is-forcing-on-to-business.
[7]See, for example, https://www.nap.edu/catalog/25038/graduate-stem-education-for-the-21st-century and https://www.nap.edu/read/24622/chapter/1.

Contextual Factors (continued)

New Enabling Technologies

Throughout the history of science, novel technologies have empowered scientists and engineers to make huge leaps forward. In past eras, the clock and the optical microscope both led to a string of discoveries that stretch down to today. More recently, the digital computer, high-throughput gene sequencers, gene-editing techniques, exquisitely sensitive detectors of ripples in space-time, underwater robots and advanced research ships all open up new opportunities for research. For example, modern gene-editing techniques, coupled with greater understanding of molecular biological processes and design principles from engineering, open up a whole new realm of synthetic biology where both molecular machines and novel organisms can be constructed. These permit researchers to test theories about how life works at the molecular and cellular level and make possible the development of a new biotechnology industry that ranges from novel sensors for environmental chemicals to new ways of manufacturing pharmaceuticals.

When it comes to novel instrumentation, NSF plays multiple roles. It supports the basic research that makes possible the design of new technologies; funds the development and deployment of ambitious new research infrastructure that creates new opportunities for science, often a decades-long process; and provides researchers with access to cutting-edge instruments and data so they can pursue research never before possible, creating the opportunity for new breakthroughs.

Responsible and Ethical Research

The evolution of new technologies and increasingly team-centered approaches to scientific breakthroughs that extend beyond geographic and disciplinary boundaries highlight the importance of ethical decision-making in STEM. Today, scientific discoveries are often accompanied by significant ethical issues. NSF's investments in research and training serve to advance the understanding of the ethical dimensions of engineering and science. Future investments will produce cutting-edge knowledge about what constitutes or promotes responsible conduct of research and develop new ways to instill this knowledge for researchers and educators at all career stages.

Data-intensive Science

Digital technologies – the computer, fast, high-density storage and high-capacity, low-latency communications networks – together with digitally-based sensing systems, innovations in quantum-based sensors, and the shift of a great deal of human interaction to the digital realm, have led to an unprecedented availability of data about the natural and human worlds, together with powerful new techniques to analyze very large quantities of data. For example, the ability to work with gene sequence data from a whole community of microorganisms in a drop of ocean water or a sample of soil has made it possible to investigate the relationship between the genetic makeup of an ecosystem and how it functions. The rate of advance in artificial intelligence (AI) and quantum information systems promises new tools to extract insights from data. Research, commerce, health and government can all benefit from these advances; however, those same advances are surfacing new questions about how to ensure that very complex tools for the analysis of data about people operate in a way that is fair and free from bias. For example, to what extent will it be possible to project behavior from the analysis of data and how should such projections be used? Advances in data-focused science dramatically expand the questions researchers can ask and answer. The potential of data-intensive science cuts across many fields and is yet another emergent source of opportunity.

Contextual Factors (continued)

Growth of Knowledge-Intensive industries and the Demand for STEM Talent

Breakthroughs in materials, data science and AI, automation, software design, social psychology, biotechnology and the ability to harness the quantum world are examples of factors that are revolutionizing the nature of work and giving rise to the industries of tomorrow. Fundamental research, spanning the spectrum from curiosity-inspired research to solutions-focused research, drives this revolution and sustains economic growth in the U.S. and elsewhere. NSF must capitalize on opportunities to intensify the rate at which research generates new ideas and technologies to keep U.S. industry and services moving forward.

Increasingly, jobs require more sophisticated levels of technical knowledge. Globally, the demand for STEM-capable workers continues to increase. Over the next few years, the number of S&E jobs in the U.S. is projected to grow about 40% faster than the non-STEM U.S. workforce.[8] Meeting this demand will require both renewed attention to STEM education and a concerted effort to ensure that all communities are fully engaged in STEM education, research and jobs. This requires reaching individuals and communities and helping teachers and researchers inspire and encourage STEM involvement and literacy. NSF's research into how education can be transformed to provide diverse learners with the requisite skills to participate in the industries of tomorrow will be vital to the nation's ability to capitalize on the fruits of research in other fields.

Global Environmental Change

Environmental change and variability have always confronted human societies. In some cases, societies have adapted; in others, they have departed. But today's world has entered a new phase of rapid environmental change. We live in a time in which the rates of change in the Earth's physical and biological systems are higher than at any time in recorded human history. The scale of humanity's impact on planetary systems has grown so that it now reaches from pole to pole – from the heights of the stratosphere to the depths of the ocean. The impacts extend from the Earth's physical climate to the natural ecosystems, global biodiversity and agricultural systems on which human society depends. The scale of human society has grown to the point where it is no longer a perturbation to Earth systems but is now a first-order driver of change. The strong, two-way coupling between society and global biophysical and biogeochemical cycles creates a system that is challenging to predict. Developing a deeper understanding of the dynamics of that system, of the changes to come and of ways to mitigate or adapt to those changes is an urgent global challenge for researchers, policymakers, farmers, utilities, municipalities and indeed, for all citizens.

An important component of global environmental change is climate change, something that has profound consequences for the habitability and sustainability of the planet on which we live. Climate change affects food, water, energy, economies, national security and quality of life through its impacts on human health, agriculture, ecosystems and water resources. Any adaptation and mitigation strategies related to climate change need to be based on robust scientific findings. In this, NSF-sponsored research is at the vanguard.

In addition to direct consequences of changes in the physical climate, such as sea level rise and ocean acidification, global environmental change includes rapid land-use change, encroachment on natural habitats, increasing potential for the emergence and spread of zoonotic diseases, depletion of biodiversity and reduction in the availability of vital ecosystem services such as pollination, resilience to coastal flooding and soil retention. Human activities have exacerbated existing environmental pressures on society and created new ones for which history provides little guidance.

NSF is in a unique position to address the fundamentally interdisciplinary topics of climate science, climate impacts and climate solutions. It can bring to bear the relevant expertise from many disciplines to provide deeper theoretical understanding of how components within the Earth system interact and give rise to emergent behavior; to represent the interaction of major components within the geosphere (e.g., atmosphere, ocean, land, sea ice, ice sheet, ecological and human systems) with fidelity in coupled dynamical models to project and analyze potential outcomes; and to explore the impact of climate change on the environment and strategies for adaptation and mitigation, including engineered solutions.

[8] U.S. Bureau of Labor Statistics (2021) https://www.bls.gov/emp/tables/stem-employment.htm.

Contextual Factors (continued)

The Changing Nature of Science

The world around us is a complex system with many interacting parts and processes. Nonlinearity in many of the relationships among its components makes understanding and prediction difficult. Yet the world around us has huge impacts on our quality of life. The ebbs and flows of the global economy, changes in the availability of clean water, cycles of conflict and the emergence and spread of agricultural and human pathogens are just a few examples of how important it is to understand the complex system formed by our natural world and human society. We are learning that many of the challenging research questions that confront society require a convergence of the perspectives and expertise of practitioners from different fields of S&E. Questions span the range from how to develop new health technologies to understanding the interplay between the availability and distribution of food, energy and water.

In several areas of S&E, a recent trend in the way research questions are developed and answered has been a growth in the co-production of knowledge, a participatory, solution-oriented approach to research that is often interdisciplinary.[9] This concept is characterized by meaningful interaction between producers and users of knowledge with a view toward accelerating both the generation of new knowledge and its mobilization to generate beneficial impacts for society. Many pressing research challenges can benefit from this approach. For example, it is well suited to enabling progress on so-called "wicked" problems in socio-environmental systems such as understanding the potential impacts of climate change and ways of mitigating these and the sustainability of ecosystem services that are vital for human well-being, including those essential for food production. Co-production promotes both the likelihood that research will produce actionable knowledge and the likelihood that such knowledge will be acted upon.

Including the Missing Millions[10]

It has been said that, "Equal opportunity is the bedrock of American democracy, and our diversity is one of our country's greatest strengths."[11] An Executive Order has called for "a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized and adversely affected by persistent poverty and inequality." Studies have pointed to ways to increase diversity in the S&E enterprise and demonstrated the value to be gained thereby. In its recent Vision 2030 report, the National Science Board (NSB) pointed out that our nation's greatest resource is its people and that to remain competitive, the U.S. must be a STEM talent powerhouse, with "a research and development workforce that pushes the frontiers of knowledge, within a strong STEM-capable workforce in which many more Americans have the skills to thrive in a knowledge and technology-intensive economy." To meet these needs, the U.S. must expand its domestic STEM talent. The NSB went on to describe the concept of the "missing millions," a vast untapped talent pool that exists as a result of the underrepresentation of women and many communities of color in the S&E workforce. By partnering with stakeholders inside and outside academia, NSF can accelerate progress in increasing diversity in the STEM workforce; for example, by catalyzing systemic changes in organizations, such as the development of more inclusive and welcoming research environments; by investing in research training at institutions that are successful in developing new talent from underrepresented groups; by promoting others to emulate proven practices; and by supporting research on how to more effectively broaden participation in STEM.

"Missing Millions" is a vast untapped talent pool that exists as a result of the underrepresentation of women and many communities of color in the S&E workforce. By partnering with stakeholders inside and outside academia, NSF can accelerate progress in increasing diversity in the STEM workforce.

[9] E.g., https://www.sciencedirect.com/science/article/pii/S0169204619305626?via%3Dihub (2020).
[10] See Section VII for a description of an Agency Priority Goal in this area.
[11] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-advancing-racial-equity-and-support-for-underserved-communities-through-the-federal-government/.

Contextual Factors (continued)

Knowledge Mobilization

At its heart, successful research creates new knowledge. However, for that knowledge to provide value it must be mobilized. Accelerating this mobilization must be a priority for NSF and to do so requires explicit attention to the main components of knowledge mobilization. The first step in mobilization is dissemination, using formal mechanisms such as scholarly publications and presentations but also less formal ones – for example, the training of students, conversations with colleagues, books and videos for a general audience, and outreach to schools and community organizations. However, knowledge mobilization goes far beyond dissemination. It follows a spiral – from the generation of new knowledge in a research project, often involving a research team, through human capital development, the development of technological expertise and the broader development of cultural capital, to specific societal benefits. In this spiral:

Contextual Factors (continued)

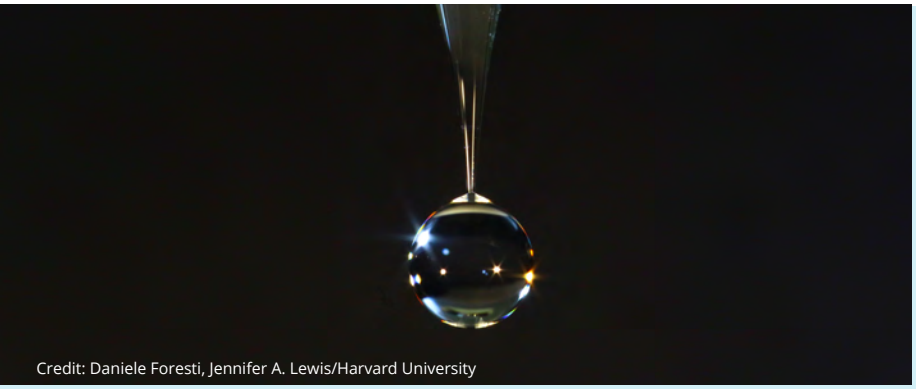
Translating Insights into Impacts

The need for scientific and technological advances that meet today's societal challenges has never been greater – from climate to energy to health care. Increasingly, the scientific and engineering communities are being called upon to address pressing societal needs: to develop solutions that improve the critical services that local communities deliver to their residents; transform higher education to meet the needs of tomorrow's workforce; inform and advance public policies; deliver the breakthroughs that will enable the industries of tomorrow; and develop ways to enhance the integrity and security of critical infrastructure. Society is demanding the impacts that NSF-funded research can provide to meet these needs and many others.

The NSB's Vision 2030 report encapsulates the trends that we are seeing today in the S&E enterprise and informs NSF's vision for translation, innovation and partnerships as mechanisms to increase the delivery of benefits from research to society. The private sector, including businesses, and especially foundations, nonprofits and other philanthropies, has dramatically increased its investment in the science and technology enterprise, offering a new opportunity for collaboration and coordination.

NSF's investments are uniquely powerful in that they support a broad spectrum of research – from exploratory and curiosity-driven to use-inspired and solutions-focused. This enables the agency to support a virtuous cycle in which insights from exploratory research prompt advances in solutions-focused research and new questions, surfaced by use-inspired research, stimulate new directions for exploration. This close synergy quickens the speed with which the spectrum of research can advance.

NSF programs such as Convergence Accelerator, centers, Innovation Corps (I-Corps™) and SBIR have provided a more sophisticated understanding of how to stimulate research focused on pressing challenges and the delivery of benefits to society[12]



Credit: Daniele Foresti, Jennifer A. Lewis/Harvard University

Credit: NSF

Partnerships for Innovation gives scientists and engineers the opportunity to increase the impact of their NSF-funded research discoveries by developing their technology into a prototype or proof of concept. The intended outcomes are commercialization of new intellectual property derived from NSF research outputs, creation of new or broader collaborations with industry, catalyzing increased corporate sponsored research, licensing research outputs to third-party corporations or startup companies funded by a PFI team, and the training of future innovation and entrepreneurial leaders.

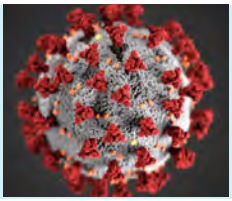
Launched in 2019, the NSF Convergence Accelerator builds upon basic research and discovery to accelerate solutions toward societal impact. The program funds teams to solve societal challenges through convergence research and innovation. To enhance its impact, the Accelerator also places teams together in cohorts, synergizing their work through facilitated collaboration.

[12] Convergence Accelerator: https://beta.nsf.gov/funding/initiatives/convergence-accelerator.
Science and Technology Centers: https://www.nsf.gov/od/oia/programs/stc/.
Engineering Research Centers: https://nsf.gov/eng/eec/erc.jsp.
iCorps: https://www.nsf.gov/news/special_reports/i-corps/.
SBIR/STTR: https://seedfund.nsf.gov/.

Opportunities and Grand Challenges

New technologies, the new availability of data, and new convergent approaches to doing science create a wealth of opportunities. NSF looks for creative ideas and novel approaches that exploit these. We will continue to use the advice of external experts and the knowledge of internal staff to identify bold but promising new ideas. We will not be afraid to take risks on original ideas, and we will nurture creativity and risk-taking in the rising generation of researchers. And we will continue to invest in cutting-edge infrastructure for research and in innovation in undergraduate and graduate education.

While we cannot predict what new ideas will emerge in the coming years, we can give examples of current opportunities for dramatic advances.



WHAT CAN WE LEARN FROM THE RECENT PANDEMIC?

The SARS-CoV-2 pandemic highlighted the need for greater research on how to predict future possible pandemics and how to mitigate their effects, and it also highlighted the importance of research on remote distributed work and remote learning.[13]

BUILDING A SUSTAINABLE FUTURE

Climate and Resilience Research and Innovation: The impacts of global environmental change are inescapable. Many species are having to cope with migration of the ecological niches to which evolution adapted them. Rising seas and changing patterns of precipitation will increasingly affect the availability and quality of naturally occurring fresh water. Changes in temperature, precipitation, wind patterns and atmospheric carbon dioxide concentrations are affecting the growth of plants on which animals and people depend and will have impacts on agricultural productivity. The Arctic is warming at twice the rate of the rest of the Earth, with far-reaching consequences for Arctic residents and the Earth system as a whole. Developments in mobile and fixed observation platforms, new sensors, wireless communication, satellite observing systems, integrated Earth system models and new techniques for the distribution, analysis and synthesis of data present an opportunity for global change research with potentially large impacts on the economy, national security and the well-being of society.

By investing in research that produces breakthroughs in science and technology, the nation can create powerful new solutions to address climate change, propelling market-driven change and economic growth and improving health and job growth, especially in communities that have been left behind. Research that increases the understanding of global environmental change and propels innovation in resilience will enable society to anticipate and adapt to change, while maintaining economic growth and improvements in well-being.

Clean-energy research: The need for energy in the United States continues to grow – for electricity generation, transportation and use in our homes, commerce and industry. Biomass, geothermal, wind, hydro, tidal and solar power have the potential to contribute a greater portion to the nation's energy mix. Research that advances materials for energy-efficient technologies, improves processes for chemical and manufacturing industries, and develops new approaches to harnessing energy from renewable sources in sustainable ways will play a critical role in achieving a carbon-neutral and equitable economy.

Collaborative research opportunities in clean energy that encourage partnering between investigators in the economic and social sciences, educational research, biological and physical sciences, computing and engineering are imperative for providing the knowledge needed to overcome the technological barriers to expanding clean energy use and consumption. As the world moves quickly from a fossil-fuel based energy system, developing a diverse technical workforce in these new fields is critical.

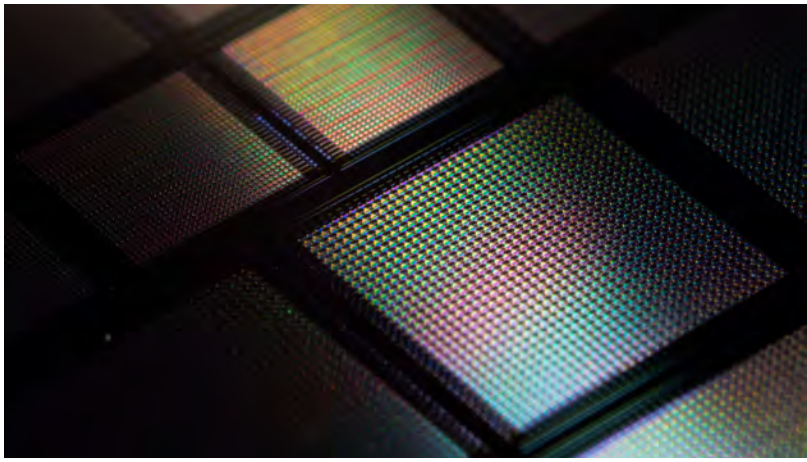
[13] During the COVID-19 pandemic, the National Academies, with support from the NSF and the Alfred P. Sloan Foundation, established the Societal Experts Action Network (SEAN) of leading experts in the social, behavioral, and economic sciences to provide rapid, actionable responses to urgent and complex policy questions from decision-makers at all levels of government. NSF also launched a new research program entitled "Predictive Intelligence for Pandemic Prevention."

Opportunities and Grand Challenges (continued)

EMERGING INDUSTRIES

Global competition for leadership and talent in science, engineering and technology is at an all-time high. For the United States to remain in the vanguard of industrialized nations, we must recommit to investing in the research that creates breakthrough technologies and powers new industries. The technologies and industries that are the focus of national conversations around competitiveness today and the ones that will emerge in the future are rooted in sustained support for research at the frontiers of science and engineering.

To create and develop emerging industries, we must advance in areas such as:



Close-up view of a new neuromorphic 'brain-on-a-chip:
Credit: Peng Lin (Creative Commons CC BY-NC-ND 3.0

Manufacturing: With breakthroughs in materials, technologies and systems, research transforms manufacturing capabilities, methods and practices. Advanced manufacturing research intersects, builds upon and contributes to developments in biotechnology, synthetic biology, sustainability, AI, robotics, sensing technologies, data science and computational modeling. Advances in manufacturing will serve to propel almost every sector of the U.S. economy, from health to IT to transportation.

Wireless Technologies: Knowledge and innovation in areas necessary for future generations of wireless technologies and networks, while ensuring security for all users, are critical for 21st century society.

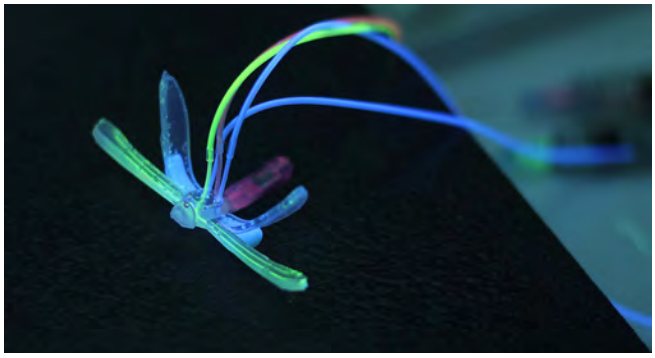
Biotechnology: Research in areas such as genomics, bioinformatics, structural and computational biology, biophysics, synthetic biology and tissue engineering, and the development of new types of biomaterials, bio-based microelectronics and biomanufacturing have given rise to a biotechnology industry. Crosscutting fundamental discoveries in biology, computing, engineering and mathematics are spurring rapid development of capabilities in biotechnology that drive innovation within the U.S. bioeconomy. For example, investigations into bacterial adaptive immune systems led to the development of the CRISPR gene editing technique, which, in turn, is now spurring new basic research in functional genomics and other fields and advancing innovation in existing industries, including health and agriculture. These innovations build on the base technology and make possible the creation of precision medicines and new methods of plant breeding. New biotechnologies will advance the U.S. bioeconomy, accelerating the ability to harness biological systems to create goods and services that contribute to agriculture, health, security, manufacturing and climate resilience. Other areas of NSF-supported research that promise transformative new biotechnologies include increased understanding of cellular assembly leading to innovations in bioprinting, research into biosynthesis that advances the development of crops resilient to extreme weather and investigations into biomechanics that are enabling bioinspired design and innovative robotics and sensors.

Quantum Science and Engineering: The development of quantum computing, communication, sensing and networking is poised to provide new technologies for information processing, transmission and measurement in ways that classical approaches do much less efficiently, or not at all. We have embarked on a revolution in which scientists exploit quantum phenomena in new and previously unforeseen ways. The result is a new paradigm that changes science, technology and everyday life. Small and exquisitely sensitive sensors and imaging tools for the laboratory and in the field, secure communication for defense and financial transactions and computation with unprecedented power are just a few examples of the potential fruits of this research.

Opportunities and Grand Challenges (continued)

EMERGING INDUSTRIES (continued)

Artificial intelligence: Data-intensive science – the interaction between people and technology – and the use of a convergent approach to research come together in the research area of AI. For example, imagine a future in which autonomous vehicles fill the roads and the sky, all the while constantly communicating with each other, the roadway and traffic control signals. Understanding the behavior of this "swarm" and ensuring that terrestrial and aerial traffic flow evolves safely and efficiently is a research challenge that requires insights from biology, mathematics, engineering, human psychology and computer science. The research addresses the problem of how to integrate large flows of data from sensors in vehicles and embedded in the roadway and visual information from cameras. The traffic flow of highways and skyways of the future is just one example of the ways in which research that provides the ability to deploy AI on a large scale will transform our lives. Other potential outcomes from research on AI and cloud computing include robot assistants for the home-bound, diagnostic systems to aid physicians, improved factory automation and, when coupled with novel approaches to the analysis of large data-streams, new tools for the intelligence community.



Soft robotic dragonfly called 'Drabot': Credit: Vardhman Kumar, Duke University

Semiconductors: Semiconductor discovery, development and fabrication and technologies for future domestic electronics foundries will provide an opportunity to address the technological and global trends in semiconductors that challenge our nation, such as the end of Moore's Law and the offshoring of semiconductor fabrication and manufacturing. A focused research effort will enable future quantum computing and networking technologies, highly parallel chip designs that will improve the performance of AI algorithms, low-power and high-performance devices that will drive a mobile and wireless future, and smart sensors that will interface between biosystems and electronics.

INFRASTRUCTURE FOR THE FUTURE

Across the country, there is a need for strong, resilient and sustainable infrastructure that strengthens communities, spurs innovation and creates American jobs. NSF seeks to leverage its all-of-science-and-engineering approach to stimulate groundbreaking research that makes American infrastructure stronger, more resilient and more cost-effective. Strong, resilient infrastructure makes public- and private-sector service delivery more efficient. It provides new ways to protect natural and built environments. It offers pathways to opportunity for long-underserved populations. And it enhances national security and fuels American leadership in critical technologies.

Research infrastructure, from individual laboratories to major research facilities, is at the heart of the scientific endeavor. It is needed for applications as varied as studying the evolution of carbon in the atmosphere, assessing the rate at which glaciers are losing ice, analyzing changes in biomass in forests, studying the rate at which underrepresented groups are engaged in S&E disciplines, modeling the epidemiology of infectious diseases, detecting gravitational waves and characterizing the contents of our solar system. Modern research infrastructure for these applications gathers and processes vast amounts of data, makes sense of those data using tools such as AI, and supplies both raw and processed data to researchers across the U.S. and around the world. If the U.S. does not lead the world in research infrastructure, it cannot lead the world in science and innovation.

Sustaining the development and implementation of state-of-the-art research infrastructure will enable discovery and innovation at the forefront of a wide variety of science disciplines. NSF will enhance access to research infrastructure to all groups across the socioeconomic spectrum, with particular attention to communities that have historically been underrepresented in S&E.

Opportunities and Grand Challenges (continued)

PEOPLE, TECHNOLOGY, AND CHANGE

The Interaction of People with Technology: Information and communications technologies and robotics have already affected many aspects of human life, transforming our work, learning, interactions within communities and even our sense of self. Today, we are at the cusp of a major expansion of those impacts that will be driven by machine learning, the Internet of Things and semi-autonomous and autonomous engineered systems. This represents a socio-technological transformation with the potential to affect society even more pervasively than the industrial revolution. Its impact will be felt at all scales: individual, organizational and societal. Learning from the rapid adaptions prompted by the pandemic and understanding the potential impacts of future changes is essential. There is an opportunity for convergence research to understand the benefits and risks of these emerging technologies and to learn how to create human-centered technologies and technology-rich environments that will enable people to pursue more satisfying and productive lives.

Conflict and Change: Investments in research on individuals, families, communities and organizations can empower society with knowledge about reducing conflict and improving cooperation. Such research will provide insights into how people can live together cooperatively in a diverse, global and more populous society. Answers to psychological questions about the relationship between conflict and cooperation and the way that feelings of trust, empathy and bias are formed in the brain can increase human capacity for compassion, trust and cooperation.

The Physics of Aging: Biological organisms, complex machines, materials, buildings and social and economic structures all lose integrity as they age and eventually fail. By bringing together insights from a wide range of topics, ranging from evolutionary biodemography to solder joint reliability, biologists, physicists, engineers and human-centered scientists seek a unified view of aging and age-related failure. By identifying quantifiable, testable questions on how living and nonliving systems age and fail; establishing commonalities and differences between engineering, physical, social and biological aging and failure; and bringing the languages of engineering reliability, aging biology, molecular biophysics and statistical mechanics together, researchers can develop a new understanding of aging.[14]

Non-equilibrium Systems: Non-equilibrium systems are encountered in many fields, including physics, biology, engineering, chemistry, materials science and economics. Their behavior is often unpredictable with our current level of understanding. Some exhibit emergent phenomena such as shocks in financial systems, the collapse of electrical grids, failures in complex engineered systems, and sudden outbreaks of disease. Often, behavior at the system level cannot be modeled or accurately predicted solely from a knowledge of the properties of the component parts. Yet these systems are often of great utility. A better ability to understand, predict and control their behavior, and to design systems to exhibit specific desired emergent behavior, will have numerous economic and social benefits.

By bringing together insights from a wide range of topics, ranging from evolutionary biodemography to solder joint reliability, biologists, physicists, engineers and human-centered scientists seek a unified view of aging and age-related failure.

Brain activity buffers against worsening anxiety: Credit: Jonathan Lee, Duke University

[14] http://physicsoflivingsystems.org/physicsofweartearaging/.

The Discovery Engine

Observing a 3D projection of an aircraft engine: Credit: Photo from ATE Centers Impact 2011 (www.atecenters.org)
Prosthetic arm from 'Human Plus: Real Lives + Real Engineering': Credit: Photo by Andrew Kelly/New York Hall of Science
Green Roof Study in New York City: Credit: Stuart Gaffin and Shaily Kedia, Center for Climate Systems Research, Columbia University

Since its inception, what NSF calls "its "Discovery Engine," its core research in science and engineering" has fueled American leadership not just in all areas of S&E, but also in military, economic, environmental and social domains. The core research that NSF funds attacks vital but difficult questions. In many cases, years of painstaking work are needed to crack the code of the grand puzzles that nature and history present to us.

Leveraging partnerships with other sectors, NSF supports science and engineering research and innovation leading to breakthrough technologies as well as solutions to national and societal challenges, sustaining and enhancing U.S. competitiveness on a global stage.

Leveraging partnerships with other sectors, NSF supports S&E research and innovation that lead to breakthrough technologies as well as solutions to national and societal problems, sustaining and enhancing U.S. competitiveness on a global stage. NSF accelerates the translation of fundamental discoveries from lab to market, advancing the U.S. economy and creates education pathways for every American to pursue new high-wage, good-quality jobs, supporting a diverse workforce of researchers, practitioners and entrepreneurs.

NSF has pioneered a world-leading approach for supporting core research. Its peer review process brings together leading experts from all over the country to give NSF the best available information on how American science can make the biggest breakthroughs and provide the greatest value to the American people. NSF has deep and vigorous relationships with every major research institution in the country. As a result, the agency can support STEM education and training in any part of the country and can identify experts in any field of science.

Attributes like these give NSF another advantage in serving the nation – we can draw, identify and support proposals that "fall between the cracks." Many of the most transformative ideas are interdisciplinary. Because of the way that NSF's component parts work together and coordinate, NSF has incredible expertise and dexterity when it comes to finding and evaluating groundbreaking ideas. If NSF receives outstanding proposals that do not fit squarely into a single academic discipline, we work together to evaluate them and support them. There are perhaps no better examples of this ability than NSF's Convergence Accelerator and Growing Convergence Research programs.

The Discovery Engine (continued)

Efforts like these have never been more important than they are today. The pandemic, increasing recognition of inequality and injustice, the rise of cyberwarfare and cyberterrorism, threats to vital social institutions, and changing environmental conditions raise the stakes on America's ability not just to produce rigorous, accurate and vitally important knowledge, but to be able to produce it at a speed and scale that none of our competitors can match.

To accomplish this goal requires America to excel at the "short game" and the "long game." The short game is the ability to transform the knowledge we have into products, practices and instruments we can use to solve problems, create change and empower people right now. The long game is making sure the knowledge base from which our country will need to draw in the future is as strong as we can make it -- with the caveat that continuing American leadership will require this knowledge base to be the best in the world.

NSF is a bedrock of America's long game. It is built to identify the types of work that will create opportunities and empower Americans for decades to come. Yet NSF's statutory mission requires always keeping the short game in focus. For this reason, NSF operates with a daily sense of urgency. We track the Nation's greatest needs, identify places where S&E advances can do the greatest good, and support the work that keeps our Nation secure, resilient, sustainable, innovative and just.

This approach has fueled generations of innovators and innovations. Outcomes from NSF's early-stage investments in core areas of science and research are seen in the internet, Google, Qualcomm, 3D printing, economic instruments that have lifted millions out of poverty and even the polymerase chain reaction (PCR) testing technique that has been critical in the fight against COVID-19. NSF's ability to play the long game -- in particular, its sustained commitment to vital research areas over multiple decades -- continues to push America to the forefront of vital technological areas such as AI and quantum information science. NSF's strategic focus on both supporting the best science at the time and planting the seeds for future research has enabled America to strengthen generation after generation.

As NSF looks to the future, the agency's capacity to continue to produce breakthroughs, innovate, identify industries of the future, accelerate the translation of research results to practice and cultivate the diverse workforce needed to power our country forward must be strengthened at speed and scale. NSF has the know-how and energy to create a brighter future for our nation.

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RapidTech 3D modeling: Credit: RapidTech

VI STRATEGIC GOALS AND OBJECTIVES

The core of NSF's strategic plan is built around four themes: empower, discover, impact and excel. The plan focuses on expanding frontiers, engaging people and delivering solutions. As described in the new vision for NSF that underlies this plan (section I: Vision), in order to promote the progress of science; to advance the national health, prosperity and welfare; and to secure the national defense in a way that harnesses the full potential of the nation, we must simultaneously make progress in advancing the frontiers of research, delivering the benefits of research to society, ensuring accessibility and inclusivity, developing STEM talent and securing global leadership in S&E. These inform the objectives of NSF's first three strategic goals. At the same time, NSF must strengthen at speed and scale its ability to meet these goals. Consequently, expanding the capacity and capability of NSF as an agency is a fourth goal, synergistic with and essential to the first three.

List of NSF Strategic Goals and Objectives 2022 – 2026

Strategic Goals	**Empower:** Empower STEM talent to fully participate in science and engineering	**Discover:** Create new knowledge about our universe, the world and ourselves	**Impact:** Benefit society by translating knowledge into solutions	**Excel:** Excel at NSF operations and management
Strategic Objectives	**Ensure accessibility and inclusivity** Increase the involvement of communities underrepresented in STEM and enhance capacity throughout the nation	**Advance the frontiers of research** Accelerate discovery through strategic investments in ideas, people and infrastructure	**Deliver benefits from research** Advance research and accelerate innovation that addresses societal challenges	**Strengthen at speed and scale** Pursue innovative strategies to strengthen and expand the agency's capacity and capabilities
	Unleash STEM talent for America Grow a diverse STEM workforce to advance the progress of science and technology	**Enhance research capability** Advance the state of the art in research practice	**Lead globally** Cultivate a global S&E community based on shared values and strategic cooperation	**Invest in people** Attract, empower and retain a talented and diverse NSF workforce
Foundations: People, Ideas, Partnerships				

As described in Appendix 3, NSF's strategic goals and objectives are shared across the agency.

Strategic Goal 1 – Empower:

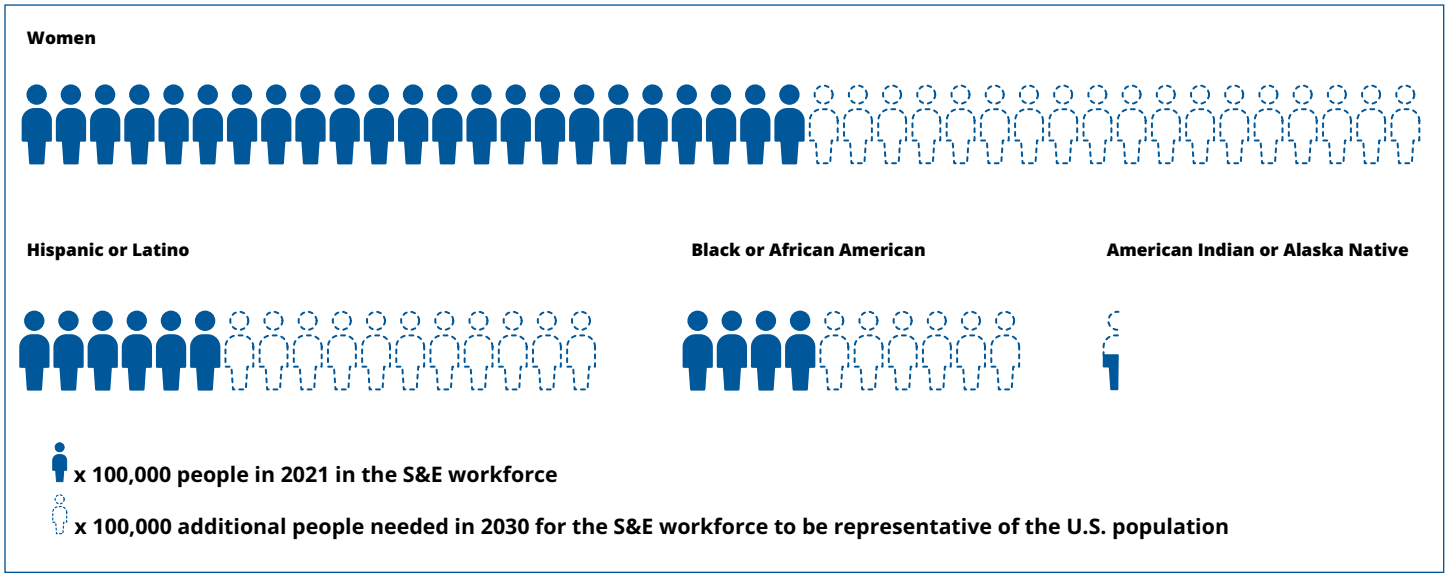
Empower STEM talent to fully participate in science and engineering

S&E are key to the nation's economic progress, and people are the core of America's scientific progress. To accelerate the advancement of discovery and learning, prepare for a world in which work is increasingly reliant upon scientific and technological skills and ensure that all citizens share in the benefits that flow from research, we must promote inclusion in the research community and STEM workforce, access to STEM learning and training and widespread STEM literacy.

Our global competitiveness depends critically on the readiness of the nation's STEM workforce, but millions of talented individuals are missing from that workforce. NSF seeks to empower these missing millions[15] by making strategic investments in researchers and research training to harness the talents and creativity of America's diverse population. NSF also supports research into practical ways to promote a scientifically literate U.S. population that is well prepared for the economy and challenges of the 21st century.

The Learning Agenda in Appendix A.1 of this plan contains a set of specific questions to help NSF assess progress on the strategic objectives listed under this goal. These reflect a guiding question: How can NSF grow STEM talent and opportunities for all Americans most equitably?

Figure 1: Missing Millions



The U.S. S&E enterprise lacks millions of people from its workforce, leadership positions and training pathways. While the number of people from underrepresented groups in the S&E workforce has grown over the past decade, much faster increases are needed for the S&E workforce to represent the U.S. population in 2030. To achieve that goal, the NSB has estimated that the number of women must nearly double, Hispanic or Latinos must triple, Black or African Americans must more than double and the number of American Indian or Alaska Native S&E workers needs to quadruple.

[15] See https://www.nsf.gov/nsb/publications/2020/nsb202015.pdf

Strategic Objective 1.1 – Ensure accessibility and inclusivity

Increase the involvement of communities underrepresented in STEM and enhance capacity throughout the nation.

Our nation's STEM workforce must reflect the diversity of our society. This is essential for the emergence of a rich set of ideas and approaches that drive discovery and innovation. In addition, our research portfolio must tackle the challenges faced by all sectors of society; for example, environmental research to explore ways of addressing environmental change that benefit the full range of socioeconomic communities across America.

Demographic Diversity

A student's socioeconomic or demographic background should not be a limiting factor in their choosing to earn a STEM degree, or in support of that pursuit. Through programs such as ADVANCE and NSF INCLUDES (Inclusion Across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science)[16] and their successors, NSF fosters institutional transformation within research and educational organizations so the nation can capitalize on the talents and ideas of all segments of the population. Through its research training activities, NSF invests in the broad diversity of STEM talent, aiming to advance racial equity and a STEM workforce that is more representative of our nation.

Credit CAHSI - Computing Alliancce of Hispanic-Serving Institusions

An Alliance to Broaden Participation in Computing

The Computing Alliance of Hispanic-Serving Institutions, supported by NSF INCLUDES and other NSF programs, has the mission to grow and sustain a networked community committed to recruiting, retaining and accelerating the progress of Hispanics in computing.

Geographic Diversity

Talent is found throughout the United States. NSF's Established Program to Stimulate Competitive Research (EPSCoR) is an example of a program that seeks to expand the geography of innovation by advancing research capacity in states and territories that receive relatively small proportions of the federal research budget. NSF will expand its efforts to ensure all parts of the U.S. participate in the 21st century S&E enterprise.

Credit: Lindsay Arvin

EPSCoR: Expanding the Geography of Innovation

NSF's Established Program to Stimulate Competitive Research (EPSCoR) has greatly expanded the research capacity of targeted jurisdictions, promoting geographic diversity of science and engineering across the United States and its territories. For example, University of Wyoming researchers led a study that found foreign dust likely fertilizes plants in many locations worldwide.

[16] ADVANCE at a Glance and NSF INCLUDES Special Report to the Nation II

Strategic Objective 1.1 – Ensure accessibility and inclusivity (continued)

Increase the involvement of communities underrepresented in STEM and enhance capacity throughout the nation.

Institutional Diversity

To maximize the impact of its research training, NSF works to increase the range of institutions it supports. Through tailored, capacity-building programs, NSF enhances the ability of specialized institutions to draw diverse communities into research and the STEM workforce. Specialized programs can also help the nation meet emergent needs for a workforce trained in the new results of research in areas such as cybersecurity, quantum information science and AI.

Improving Accessibility

As a preeminent funder of research, it is vital for NSF to ensure that everyone with potential has an opportunity to contribute to advancing the research frontier. NSF will continue to modernize its outreach to potential new investigators and institutions, combining both direct in-person outreach, support for research development assistance efforts of external partners, and online tools to make it easier to submit proposals and manage grants.

NSF 101

NSF 101 is an informational series for the S&E research community, written for those who may be new to the application process for NSF funding opportunities. NSF 101 provides clear, basic instructions that improve accessibility by demystifying the process of seeking funding from NSF, engaging with NSF program officers, and understanding NSF's merit review criteria.

By promoting the participation of undergraduates, graduate students and postdoctoral associates from all communities in research projects, as well as by providing graduate and postdoctoral fellowships and research experiences to an intentionally diverse array of undergraduates, K-12 students and teachers, NSF supports the development of a new generation of researchers, scholars and knowledge workers that better represents our pluralistic society. It prepares both future research leaders and a STEM workforce that is equipped with up-to-date knowledge and the experience needed to address society's current and future challenges.

Indicators of progress towards this objective could include increases in the proportion of proposals that come from groups, regions and types of organizations that are underrepresented in NSF's proposal portfolio.

Strategic Objective 1.2 – Unleash STEM talent for America

Grow a diverse STEM workforce to advance the progress of science and technology.

Tomorrow's advances in S&E will be accomplished by people educated today, in K-12 and college settings as well as in informal environments. One of NSF's most important approaches to advancing the progress of science and technology is to inspire and invest in the development of the next generation of our nation's STEM workforce, both within and beyond the academic environment. By leveraging its investments in research training and research on STEM learning, NSF supports a national effort to grow the next generation of discoverers and skilled technical workers and, in the process, entrain the missing millions and increase the diversity of the STEM workforce. This includes support for research that will develop and test new models for the lifetime integration of career and technical training, to keep pace with the ever-expanding frontiers of knowledge.

Research on STEM Education

NSF supports research in STEM education and on effective approaches to preparing a diverse, globally competent STEM workforce and a STEM-literate citizenry. The research in learning in which NSF invests is aimed at both formal and informal pathways. Formal education through the nation's K-12 schools provides the foundation for citizens' understanding of STEM and its uses in addressing the needs of society. The formal education process continues through our nation's colleges and universities, where scholarship is the hallmark. Informal education -- from the nation's science museums to children's educational television -- is a powerful means to diffuse knowledge, provide learning and instill interest in STEM topics in everyone throughout their lives. NSF invests in research about education to develop more effective approaches to engage the public and help citizens develop a better understanding of science and the scientific process.

NSF's investments in research on STEM education extend the reach of its S&E programs by paving the way to integrating their results into modern approaches to learning. Programs such as Improving Undergraduate STEM Education and Innovations in Graduate Education involve research that leads to improvements in undergraduate and graduate STEM programs, while Education and Human Resources Core Research advances learning, learning environments, workforce and broadening participation at all levels.

Formal Education and Research Training

Institutions of higher education in the U.S. play an important role in educating a diverse STEM workforce beyond preparing students for careers in research. NSF invests in postdoctoral, graduate and undergraduate research training through funding for research projects, research centers and research fellowships and by providing research experiences for undergraduates at home and abroad. NSF funds research on ways to improve graduate and undergraduate education to prepare students to participate in the nation's scientific and technological workforce. It provides opportunities for institutions of higher education to pilot new approaches to education that put the results of this research to good use. And NSF pursues innovations in undergraduate education aimed at better preparing the skilled technical workforce of the future. These efforts support the nation in developing a STEM workforce with broad capabilities for careers in business, industry and academia. To strengthen the links between precollege teaching and the frontiers of knowledge, NSF supports research experiences for educators.

Studying why lithium batteries fail.: Credit: David Baillot/UC San Diego Jacobs School of Engineering

Strategic Objective 1.2 – Unleash STEM talent for America (continued)

Grow a diverse STEM workforce to advance the progress of science and technology.

Informal Education

Informal education is another powerful means to diffuse knowledge, provide learning and instill interest in STEM topics in everyone throughout their lives.

Citizen-engaged science, for example, fosters informal education and involves citizens in a meaningful, gratifying way as it advances science at the same time. NSF invests in research on informal education that is intended to develop more effective approaches to engaging the public and to help citizens develop a better understanding of science and the scientific process.

Indicators of progress towards this objective could include increases in the number and diversity of students, teachers and members of the public who participate in NSF formal and informal education activities.

Credit: Val Sloan

Research Experiences for Undergraduates (REU)

NSF funds a large number of research opportunities for undergraduate students through its REU Sites program. An REU Site consists of a group of ten or so undergraduates who work in the research programs of the host institution. Each student is associated with a specific research project, where he or she works closely with the faculty and other researchers. Students are granted stipends and, in many cases, assistance with housing and travel. These experiences have inspired many students to pursue careers in research and science. REU Sites make a special effort to recruit from groups underrepresented in science and engineering.

Closing

Scientific understanding is key to meeting many of the major challenges that confront society, from adapting to the impacts of climate change to overcoming the barriers to racial equity in society. To meet these challenges requires the involvement of society as a whole. NSF's efforts to mobilize knowledge more broadly and promote scientific literacy, in partnership with other U.S. and state agencies, are strategic imperatives for the agency.

Strategic Goal 2 – Discover:

Create new knowledge about our universe, our world and ourselves.

This goal furthers the first part of NSF's mission, "to promote the progress of science," pursuing the generation of new knowledge so the nation remains a global leader in expanding discovery in science, engineering and learning. By generating new knowledge, NSF-funded researchers provide the nation with the capability to maintain scientific, technological and economic leadership in a competitive world.

Fundamental research is a capital investment for the nation. Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.[17] Those practical applications of knowledge sometimes begin to be realized very quickly; for example, some of NSF's investments in research related to the SARS-CoV-2 pandemic produced actionable results within months. In other cases, the practical applications may not be fully felt until decades after the initial basic research. A connection between fluid dynamics and an improved industrial process may be easier to foresee than the practical benefits of fundamental physics research into what Einstein called "spooky action at a distance," but the initial research on quantum mechanics in the early 20th century paved the way for the development of new approaches to secure communications and more powerful computers that is underway in the 21st century's research on quantum information systems.

A piece of the quantum puzzle: Credit: P. Roushan\Martinis lab\UC Santa Barbara

Quantum Information Technologies

NSF partners with researchers in academia and industry to pioneer breakthrough technologies. For example, in the pursuit of a scalable, universal quantum computing platform, NSF is supporting an innovative company to develop technology that will enable the use of neutral atoms as a platform for scalable quantum computing with fault-tolerant capabilities. With a previously unrealized degree of coherent control to atomic systems, the system will serve as a novel tool to study many-body physics, enabling new quantum simulations of new phases of matter or high-energy physics.

[17] V. Bush (1945). "Science: The Endless Frontier." Transactions of the Kansas Academy of Science, vol. 48, pp. 231-264.

Strategic Goal 2 – Discover: (continued)

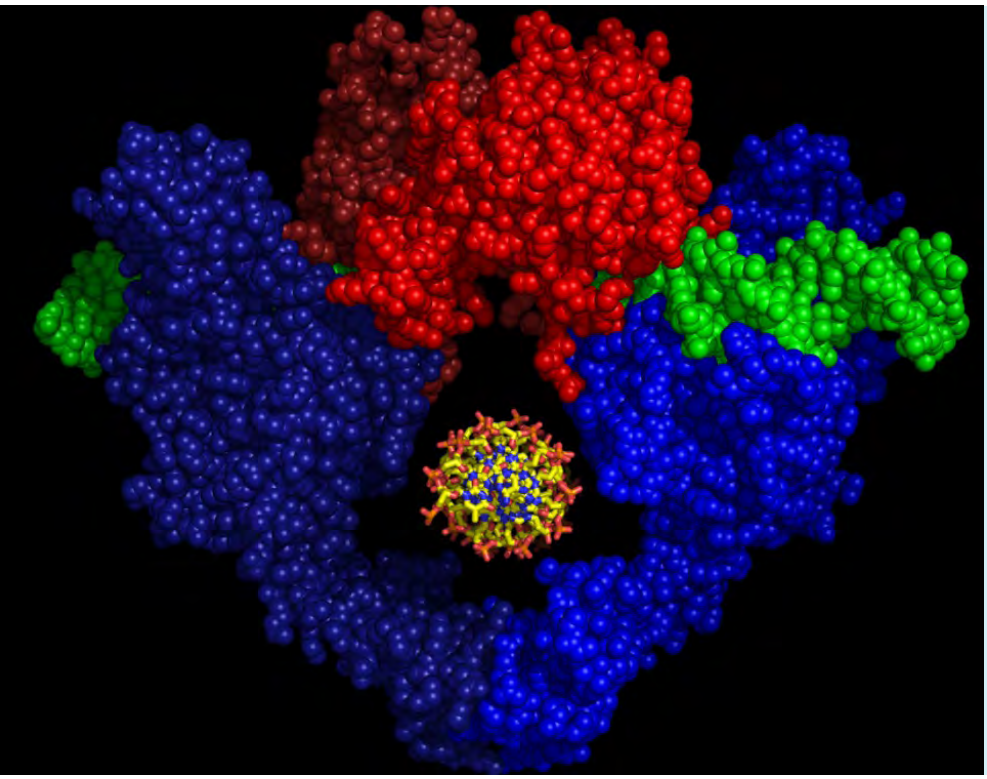
Create new knowledge about our universe, our world, and ourselves.

Just as financial advisors stress the importance of diversifying investments, so the benefits of research are maximized when a wealth of different fields and research questions are supported. NSF embodies this by supporting all fields of basic science, engineering and STEM learning research. NSF welcomes proposals for original research and for new tools, such as advanced instrumentation, data analysis, computation and novel facilities. Investment in competitively selected projects expands the knowledge base from which innovation springs. A special role of NSF is to encourage creative efforts that may not fit within the domain of specific mission agencies.

NSF fosters a culture of "smart risk-taking" and cultivates the spirit of exploration in researchers and students. Reviewers are encouraged to look for high potential rewards that justify taking risks to support projects that may not always work as planned.

NSF provides leadership in an evolving global research enterprise by supporting modern collaborative approaches to science, funding research within and between traditional fields and strengthening interactions between U.S. researchers and their leading counterparts abroad. By using novel funding mechanisms for exploratory research, NSF catalyzes and incubates new fields of research and the search for new insights that disrupt traditional understanding.

The Learning Agenda Appendix A.1 contains a set of specific questions to help NSF assess progress on the strategic objectives listed under this goal. These reflect a guiding question: How can NSF fuel transformative discoveries most effectively?



Credit: Figure courtesy of James M. Berger, UC-Berkeley

Enabling the biotechnology industry

NSF supported exploratory research into the mechanisms behind how bacteria acquire immunity against viral infection. The curiosity-driven project investigated the function of the protein Cas9 and how it disrupts viral DNA in bacteria. Building on decades of research, Jennifer Doudna and Emmanuelle Charpentier teamed up to fuse tracr-RNA and CRISPR-RNA to produce what they called guide RNA, a tool that enables cleavage of DNA molecules at extremely precise locations, based on how the guide RNA was designed. This technology continues to transform the way we understand gene regulation.

Strategic Objective 2.1 – Advance the frontiers of research

Accelerate discovery through strategic investments in ideas, people and infrastructure.

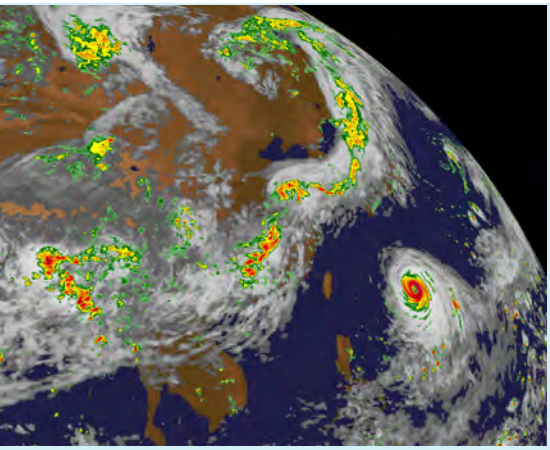
A Spectrum of Research Investments

NSF's core objective is to improve the collective understanding of the natural, human and built facets of the universe we inhabit. To achieve this, we pursue a strategy that strengthens the U.S. research enterprise by scaling up effective approaches to research and research training in ways that speed the pace of discovery. We support a continuum of research from exploratory to solutions-focused. We look to expand partnerships with philanthropic foundations and industry to quicken the pace of discovery and the dissemination of the knowledge gained. We invest in discovery and discoverers in all areas of science, technology and STEM education research. We seek the best research ideas, both those that advance current understanding and those that disrupt it. We support world-class scientific facilities for the nation's researchers at home and abroad. We support the development and acquisition of advanced research platforms, instrumentation and cyberinfrastructure, providing 21st century tools for 21st century research.

Research with Impact

The formulation of research questions whose answers will have a meaningful societal impact benefits from engaging stakeholders outside the research community. In some cases, the execution of such research can be strengthened by the active involvement of stakeholders in shaping and facilitating the research and evaluating intermediate results.

Through workshops, specific solicitations and standing programs, NSF helps focus the attention of the research community on fundamental aspects of high-priority national challenges. We support researchers in identifying particularly urgent questions and opening up new avenues to address these priorities. And we provide funding to pursue better understanding of specific challenges that confront society. These approaches promote impact-driven, use-inspired research.



Credit: Courtesy of Center for Ocean-Land-Atmosphere Studies

LEAP: reducing the uncertainty in climate projections.

Projections of future climate from Earth system models (ESMs) play a critical role in addressing the threats posed by climate change and planning for conditions that have no historical precedent. But ESM projections have large uncertainties, and the most worrisome forms of climate change are often the ones with the greatest uncertainties. Uncertainty is not unexpected considering the many processes – from cloud formation to carbon cycling to ocean turbulence – that affect the climatic response to anthropogenic forcing. These processes must be represented in models, but there is no easy way to simulate them. Some, like ocean turbulence, are hard simply because they involve very small spatial scales. Others, like the exchange of water and carbon dioxide through a forest canopy, are only incompletely understood.

Processes that cannot be explicitly represented are incorporated through "parameterizations." These are based on theory, but they also involve approximations and must be "tuned" by assigning numerical values to the parameters which control their behavior. The complexity and computational expense of ESMs has increased to the point where the traditional approach is becoming impractical. The Center for Learning the Earth with Artificial Intelligence and Physics (LEAP) applies AI to the wealth of available Earth system data to overcome the limitations of traditional parameterizations, creating a new pathway to better ESMs and better climate projections. The AI methods build physical constraints into data-driven algorithms. They are also used to find more discriminating ways to use observational data to evaluate model performance.

Strategic Objective 2.1 – Advance the frontiers of research (continued)

Accelerate discovery through strategic investments in ideas, people and infrastructure.

Innovation and Entrepreneurship

Innovation and entrepreneurship are key capabilities for the nation. NSF's investments in S&E research and training foster innovation across a broad range of topics relevant to technological and economic competitiveness. Examples include advanced manufacturing, the design of innovative materials and building technologies, infrastructure resilience and sustainability, mitigating and adapting to the effects of global environmental change, innovations in AI, decision-making, cybersecurity and data analytics. Through its Convergence Accelerator, Partnerships for Innovation and I-Corps programs, NSF expands its use-inspired research portfolio and fosters a national innovation ecosystem by encouraging institutions, scientists, engineers and entrepreneurs to explore the innovation and commercial potential of their research.

The rate at which the frontiers of science advance is notoriously difficult to quantify; however, an example of an indicator of progress could be trends in publications and citations, such as those highlighted in the biennial report Science and Engineering Indicators.

NSF: transforming the world through science: Credit: Nicolle Rager Fuller, National Science Foundation

From Lab to Marketplace: Testing the Waters

NSF's I-Corps is an experiential learning opportunity to help scientists and engineers assess the potential to translate their innovation from the lab to the marketplace. Teams of three — a technical lead, entrepreneurial lead and business mentor — participate in the seven-week program and learn the art of customer discovery and business planning from seasoned entrepreneurs. The lead participants must have been funded by NSF as a researcher or student in the previous five years.

Strategic Objective 2.2 – Enhance research capability

Advance the state of the art in research practice.

Advance the state of the art in research practice

NSF seeks to advance the state of the art in research and strengthen the speed and scale at which the outputs from research benefit society. We will do this by encouraging innovation; strengthening partnerships between academic researchers, industry and other stakeholders; cultivating an inclusive and ethical research culture; embracing the growth of convergence as an approach to research; emphasizing the synergy between curiosity-driven and use-inspired research; supporting training in entrepreneurship and innovation; and supporting new modes of research practice. Research practice will also be advanced by promoting open data sharing; strengthening and broadening the community of research organizations; ensuring a safe, nurturing and inclusive research environment for all participants; leveraging partnerships with industry, civic society organizations and others to accelerate the pace of discoveries and their translation into benefits for society; and piloting new approaches to the formulation of research questions and the pursuit of their answers

Collaboration and Interdisciplinarity

There is growing consensus that some of the most intractable problems in the scientific, technological and social arenas require perspectives and approaches from multiple disciplines.[18] Indicators include the proliferation of multidisciplinary institutes and centers in academia and the private sector, new faculty hires with joint appointments and the merging of university departments. NSF has long recognized the potential synergies that result in such settings and the creativity that collaborative research and "team science" can bring to addressing some of society's most pressing research challenges. Convergent research, together with open data sharing among disparate disciplines, can lead to unprecedented breakthroughs and nucleate entirely new disciplines. NSF remains committed to maintaining a wide variety of mechanisms for supporting collaborative and interdisciplinary research at scales from small teams to multi-institutional centers.

Reproducible research

Working with the research community, NSF will promote the use of best practices to ensure that research is reproducible, including emphasizing the open availability of results and the data that support them.

Indicators of progress towards this objective could include growth in the number of records in NSF's Public Access Repository.

Chinese chestnut, an example of the diversity of rosids in temperate habitats.
Credit: Miao Sun, Department of Biology, Aarhus University

Closing

NSF will promote an academic culture that encourages risk taking, is broadly inclusive in both its demography and range of intellectual ideas, has access to cutting-edge infrastructure and is globally engaged with increased opportunities for exchanging ideas and collaborating on an international scale. It will increase opportunities for broadening the training of U.S. graduate students and early career researchers through international exchange activities and partnerships with industry.

[18] See,(1) Roco (2020) "Principles of convergence in nature and society and their application: from nanoscale, digits, and logic steps to global progress", Nanopart. Res. (2020) 22:321 https://doi.org/10.1007/s11051-020-05032-0, and references therein; (2) OECD (2020) "Addressing societal challenges using transdisciplinary research", OECD Science, Technology, and Industry Policy Paper #88, https://www.oecd-ilibrary.org/science-and-technology/addressing-societal-challenges-using-transdisciplinary-research_0ca0ca45-en.

Strategic Goal 3 – Impact:

Benefit society by translating knowledge into solutions.

NSF has since its creation in 1950, impacted society not only in the U.S. but also around the world. From groundbreaking discoveries used for medicine and gene therapies to cybersecurity research that protects individuals, corporations and governments alike, NSF has been at the forefront of scientific discovery and technological advancements improving society for this generation and the next.

Curiosity-driven, discovery-based explorations and use-inspired, solutions-focused innovations are part of NSF's DNA. The scientific pursuit of knowledge and understanding is part of the development of new technological capabilities. And in turn, those new capabilities allow us to pursue new research questions that were either unseen or out of our reach.

For the past 70 years, NSF has made transformative impacts possible through strategic, long-term commitments to advancing the entire spectrum of research, and through partnerships to catalyze new ideas, new discoveries and new technologies.

Decades of investment have positioned the U.S. as the world leader in curiosity-driven research and resulted in breakthroughs in emerging fields from renewable energy to quantum computing and AI. These discoveries have also resulted in translation of research and innovations that have changed the world – from smartphones to 3D printing and much more.

To accelerate translation of knowledge to innovation outcomes requires looking at all the components that make it possible – partnerships, infrastructure, and most importantly, people. NSF advances scientific careers by providing the support needed for researchers to explore bold ideas. For example, NSF has a multitude of programs, fellowships and career awards to strengthen pathways into STEM fields, increase diversity and expand our reach into all communities where talent exists.

By engaging stakeholders outside the research community, research questions whose answers will have a meaningful societal impact can be more readily identified. Such research is strengthened by the active involvement of stakeholders in shaping and facilitating the research, as well as in evaluating intermediate results.

NSF funds graduate student training program QISE-Net: Credit: David Awschalom, University of Chicago

Jump-starting the Quantum Revolution

NSF's strategic investments in foundational R&D have jump-started the quantum revolution. NSF-funded researchers are laying the groundwork for quantum technologies by developing new materials and components. Efforts to develop a viable quantum computer could advance multiple fields including AI, personalized drug development and weather forecasting.

The outputs of NSF's investments are new insights into the natural, built and human world. They promote U.S. leadership in topics of strategic national interest. They are captured and disseminated in research papers in journals and conferences, patents, new approaches to education and training, as startup enterprises and in technology licenses. Through partnerships between academia, governments, nonprofits and industry, the exchange of knowledge and resources helps shape a vibrant research agenda in which research questions are inspired by practical challenges, and stronger connections between researchers and potential users speed the uptake of results.

The Learning Agenda (Appendix A.1) contains a set of specific questions to help NSF assess progress on the strategic objectives listed under this goal. These reflect a guiding question: How can NSF mobilize knowledge most effectively to impact society?

Strategic Objective 3.1 - Deliver benefits from research

Advance research and accelerate innovation that addresses societal challenges.

Connecting Research and Innovation

The first part of NSF's mission is to create new knowledge and expand the nation's intellectual capital. However, NSF's mission does not end there. To advance the national prosperity, we must continue to invest in research that: (1) connects new knowledge to innovations that drive the nation's competitiveness and fuel the nation's economic growth; and (2) addresses present and emerging societal needs. NSF will continue to pursue connections between new insights and global challenges (often involving essential interdisciplinary collaborations, prototypes and technologies).

One approach to developing these connections is through partnerships to promote and catalyze the translation of research into application. NSF will expand its partnerships with other government agencies, academia and private and international entities. Such partnerships leverage NSF's resources and help ensure that fundamental research outcomes are translated into benefits to society.

Engaged Research[19]

Tools to advance research that provides the capability to meet pressing societal needs include: increasing support for the coproduction of discoveries; supporting mechanisms and training for researchers in techniques to promote the beneficial uptake of the results of their use-inspired research; and diversifying the research workforce to bring a broader range of perspectives to the generation of research questions.

In the coming years and decades, the increasing impact of humanity on the natural world – and the increasing rate and reach of the communication of ideas in the digital world -- will present the research community with urgent and increasingly global questions. Such questions include how to mitigate increasingly pervasive pollution, how to slow or adapt to the accelerating pace of environmental and ecosystem change, how to handle the emergence of new diseases, and how to address the dissemination of misinformation.

To tackle these challenges, NSF will support U.S. researchers' involvement in global research collaborations. The research discoveries and technological advances supported by NSF have never been more important to both daily life and the long-term challenges that confront national and global society.

Open Research

To accelerate both research and innovation, it is critical to make results and knowledge widely available.[20] NSF will continue to promote the rapid and wide-spread dissemination of the results of NSF-funded research with no or minimal restrictions from publication embargoes. It will encourage the use of novel means of disseminating new knowledge. And it will expand its efforts to ensure that the data cited to support published research are readily available to other researchers and well curated. Access to data is important not only so that others can build on published results but also so that key results can be tested to ensure they are reproducible.

Indicators of progress towards this objective could include growth in the number of partnerships spanning academia, industry, nonprofits, and state and local government resulting from NSF grants. NSF anticipates these partnerships being greatly accelerated by the Directorate for Technology, Innovation and Partnerships' investments.

New NSF ERC CISTAR: Credit: John Underwood, Purdue University

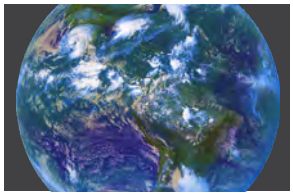
[19]See, for example, Lemos, M. C., C. Kirchhoff & V. Ramparasad (2012) "Narrowing the Climate Information Usability Gap." Nature Climate Change, 2, 789-94.
[20]See, for example, David, P.A. (2007) "The Historical Origins of 'Open Science'." SIEPR Discussion Paper No. 06-38.

Strategic Objective 3.2 – Lead globally

Cultivate a global S&E community based on shared values and strategic cooperation.

The critical importance of research and innovation as drivers of future growth is recognized around the world.[21] As noted by the U.S. Congress, many countries are increasing their investments in fundamental research.[22]

The focus on international collaboration in S&E is based on discovery, learning and research infrastructure to engage a diverse science community from different nations and cultural backgrounds. NSF develops international scientific collaborations on all seven continents and provides opportunities for researchers to enhance their work through international cooperation.



A Global Footprint

NSF's Office of International Science and Engineering (OISE) leverages NSF and world resources through international collaboration to advance the frontiers of science. It promotes an integrated, foundation-wide, international engagement strategy and manages internationally- focused programs that are innovative and catalytic. OISE promotes innovation among the U.S. research community through access to international knowledge, infrastructure and capabilities.

Research Integrity

It is vital that the U.S. remain a leader in the global S&E enterprise. In addition to generating new ideas and nurturing new discoverers and innovators, NSF leads through the values that it brings to scientific work, including open inquiry, integrity and inclusion. U.S. researchers in international collaborative projects reinforce the integrity with which international research is conducted, promote open access to data and broaden the range of participants involved.

Global, Secure Collaboration

NSF facilitates the participation of U.S. scientists and engineers in international research partnerships. Many of today's great scientific challenges, such as climate change, the degradation of environmental services, food security and the availability of fresh water and clean energy, are global in scale and require global solutions. Pioneering observations in physics and astronomy increasingly require complex infrastructure designed and implemented by teams of hundreds or thousands of experts from around the world. Because of this, NSF must continue to participate in international research infrastructure development.

A Global Effort: Imaging a Black Hole

The Event Horizon Telescope (EHT) – a planet-scale array of eight ground-based radio telescopes forged through international collaboration – was designed to capture images of a black hole. In 2019, researchers succeeded in obtaining the first direct visual evidence of a supermassive black hole and its "shadow."

As has been demonstrated many times, the impact of domestic talent is magnified when NSF also attracts foreign talent to the research enterprise. NSF works with its federal partners to reduce barriers to such participation when it accords with the key values that underlie U.S. research. At the same time, NSF continues to enhance research security through the work of its Research Security Strategy and Policy staff, building on the report *Fundamental Research Security*[23].

Indicators of progress towards this objective could include growth in the number of NSF awards that include international activity.

Closing

Breakthroughs in S&E provide new industries and jobs, enhance food and water security, and will enable America and the world to meet the challenges of the 21st century. NSF will focus the research community on accelerating the impacts of its research.

A Global Footprint: Credit: National Science Foundation
A Global Effort: Imaging a Black Hole: Credit EHT Collaboration (Available under Creative Commons Attribution 4.0 International)

Strategic Goal 4 – Excel:

Excel at NSF operations and management.

The first three strategic goals are associated with quickly evolving challenges. Meeting these and effectively fulfilling NSF's mission requires blending strong scientific leadership with robust organizational leadership. Both are characterized by vision and flexibility. NSF will reinforce its capacity to scale rapidly to advance an expanding portfolio that meets the growing need for breakthroughs in research and innovation.

With the rapidly growing importance of exploratory and solutions-focused research for securing economic competitiveness and meeting pressing societal challenges, NSF must expand and strengthen the speed and scale at which research is conducted, research products are delivered and research and innovation communities grow.

New Ways of Working

The pandemic of 2020 and 2021 not only disrupted many research activities, but also heightened the importance of exploring new ways of working and learning, and of leveraging the technologies that support remote participation that have been made possible by earlier NSF research investments.

In 2020, NSF both celebrated its 70th anniversary and, in response to the SARS-CoV-2 pandemic, rapidly transformed itself from an organization that conducted much of its work in person to one that operated in a distributed, virtual way. Much of the technology needed to support this transition was already in use at NSF, but the response to the external impetus of the pandemic showed how rapidly the Foundation could adapt to new ways of working. This experience has created an opportunity for NSF to capitalize on the lessons learned during the pandemic and accelerate its evolution as an agile, efficient and effective organization.

NSF's Convergence Accelerator pilot demonstrated the ability to translate growth in NSF's budget to speeding the delivery of the results of fundamental research to stakeholders who are well prepared to make use of it. NSF will build on this success, expanding this type of accelerated delivery of use-inspired research as the growth in NSF's resources permits. Using a model that engages a broad range of stakeholders in the identification of new tracks for focused use-inspired research and promotes partnership opportunities using approaches developed in the commercial technology accelerator environment, the Convergence Accelerator has the capacity to increase the translation of research into practice, stimulate innovation and provide a fruitful avenue through which external stakeholders can develop partnerships with the academic and non-profit research community.

Building on Renewing NSF

NSF launched the Renewing NSF initiative four years ago, and it has been instrumental in enabling the agency to maintain uninterrupted operations throughout the pandemic (see example, "Promoting an Agile NSF"). It now points the way toward realizing the benefits of speed and scale envisioned in this plan. Renewing NSF has seeded a host of opportunities, such as: making greater use of options for remote work and a hybrid workforce; constantly seeking ways to streamline, standardize, and simplify processes and practices; expanding and deepening public and private partnerships; and always finding new ways to harness innovations in information technology and data science in the agency's work.

Global directional sign at Antarctica's Palmer Station: Credit: Ken Keenan

Strategic Goal 4 – Excel: (continued)

Excel at NSF operations and management.

Promoting an Agile NSF

The Renewing NSF initiative was launched in FY 2017 as an agency-wide reform and modernization effort. It has supported and coordinated a set of diverse and broad-based actions that have worked to transform NSF into an organization that is even more agile and responsive to the 21st-century scientific, engineering and education enterprise. It began with a series of agency-wide engagements, and from those discussions, four thematic pillars emerged:

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

These themes have guided the agency in the ensuing years, and they have enabled the agency to adapt and pivot in ways that were unimaginable when the initiative was launched.

For example, the swiftness of NSF's transition to nearly 100% telework in March 2020 was possible because of technology investments and employee engagement strategies that were already underway as part of Renewing NSF. Investments in tools for collaboration and virtual meetings were identified and prioritized in early stages of the initiative. Efforts under the Streamlining theme included the staged roll-out, beginning in October 2019, of a new electronic document routing system, replacing a long-standing paper-based process for routing and approving documents. As part of the pivot to remote operations for COVID-19, this roll-out was accelerated, ensuring that review and approval procedures continued without significant disruption, even during the first weeks of the pandemic.

Under the Workforce theme, NSF had prioritized updating policies governing telework and therefore had the necessary structures already in place to facilitate rapid expansion of telework practices. This has brought new attention and focus to operating with a geographically dispersed workforce. Efforts under the Workforce theme were re-prioritized to leverage the agency's experience with virtual operations, with a special focus on the feasibility and desirability of moving toward a hybrid NSF workforce that includes long-term telework and remote work.

Strategic Goal 4 – Excel: (continued)

Excel at NSF operations and management.

NSF will grow its capacity to promote and implement enterprise-scale adaptation and innovation, allowing the agency to continuously meet evolving challenges and opportunities. It will continue to coordinate across the agency the activities begun under Renewing NSF. The agency will pursue a transition from Renewing NSF to a longer-term, sustainable enterprise excellence capacity that will secure the benefits of coordinated, continuous organizational adaptation. This transition will establish a robust, scalable mechanism to support and facilitate changes, both those already begun under Renewing NSF and new activities. This will further catalyze enterprise-scale organizational adaptation and advance the transformative vision of a 21st century NSF. It will enhance NSF's ability to respond to the future illustrated in the NSB's Vision 2030 report.

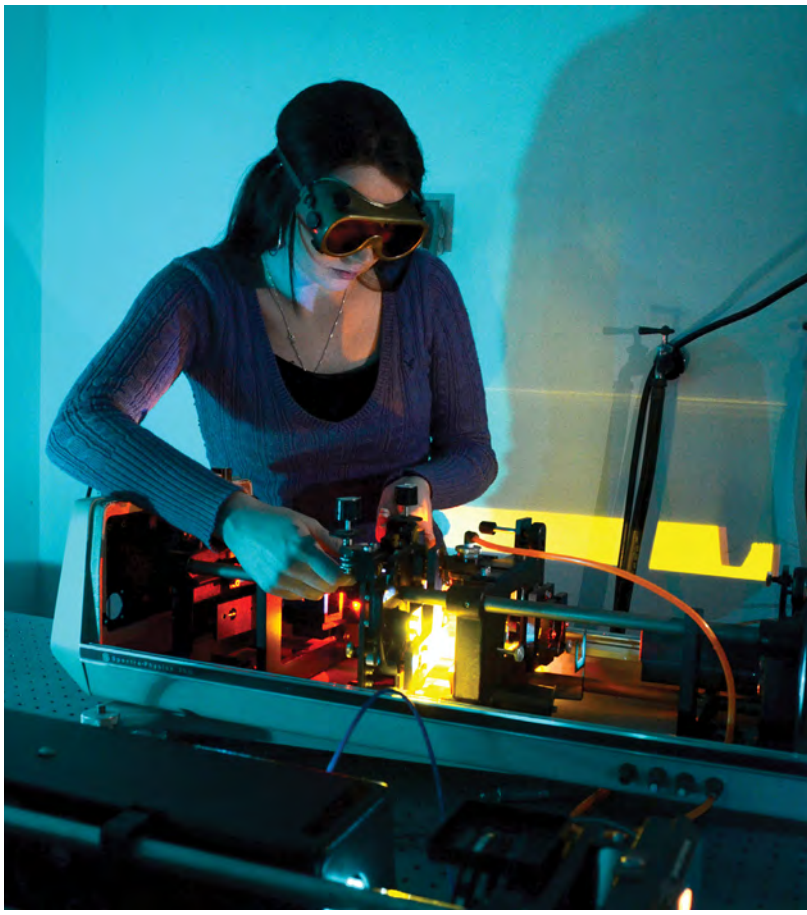
Stewardship

To ensure wise and effective stewardship of a growing budget, NSF's management objectives, described below, have the goal of advancing organizational excellence by accelerating NSF's culture of continuous improvement and maintaining high standards while growing its workforce and continuing to take advantage of cutting-edge technologies. NSF will continue to ensure that NSF's programs are effective and accountable, that the merit review process is of high quality and integrity, and that financial management and award oversight are rigorous without unduly burdening awardees. At the same time, the Foundation will look for opportunities to pilot new technology, leverage data science and develop organizational structures to meet new strategic opportunities and the changing nature of research.

Workforce

NSF's core strength is its people, and the agency remains committed to recruiting, retaining and deepening the expertise and capabilities of its entire workforce. NSF embraces an inclusive and diverse workforce. NSF's commitment to the innovative management of agency operations leverages the creativity of NSF staff with the opportunities provided by advances in information technology and training. NSF aims to drive improvements in its programs, processes and systems while providing high-quality service and support to all stakeholders. NSF also strives to align operational plans, budgets and management practices with agency goals and priorities to create a common vision that permeates the many functions of NSF and enhances the performance of both individuals and internal organizations.

The Learning Agenda (Appendix A.1) contains a set of specific questions to help NSF assess progress on the strategic objectives listed under this goal. These reflect a guiding question: how can NSF excel in stewarding and realizing its vision?



Combining technical knowledge and hands-on skills: Credit: ATE Centers Impact 2016-2017 (www.atecenters.org)

Strategic Objective 4.1 – Strengthen at Speed and Scale

Pursue innovative strategies to strengthen and expand the agency's capacity and capabilities.

Strengthening and Streamlining Processes

NSF's goal of strengthening the speed and scale of its investments in fundamental research and their translation into societal benefits makes increases in the capacity and speed of internal processes essential. Such increases must be achieved while preserving timeliness, transparency, accuracy and accountability. To accommodate growth in NSF's portfolio and the rapid evolution in the nature of research and the research community, NSF continually re-examines its organizational structure and processes to make sure that they adapt and scale to the changing role of the agency. One example of this is the Renewing NSF activity, which began in the summer of 2017.

NSF will pursue sustainable enterprise excellence through a continuing agency-wide change initiative that builds on the foundational work of Renewing NSF. This initiative aims to enhance performance of NSF's mission and maintain U.S. leadership in research and education across all areas of STEM. This effort is aligned with NSF's history of continuous organizational improvement. It will yield an even more agile organization better prepared for future challenges and opportunities.

The four focus areas remain:

- Making information technology work even better for all;
- Adapting the workforce and the work
- Streamlining, standardizing and simplifying processes and practices; and;
- Expanding and deepening public and private partnerships.

Drawing on lessons learned in the SARS-CoV-2 pandemic, one anticipated change in NSF's processes will be the transition to a structure in which, on any given day, an increased number of staff members are working remotely, compared to before the pandemic, and many review panels, oversight visits and scientific meetings are conducted virtually. This transition will require new training in areas ranging from the management of remote workers to the successful facilitation of meetings conducted by videoconference. It will also require greater use of collaboration software.

At the same time, this transition provides opportunities to expand the pool of talent from which NSF can draw, whether in recruiting reviewers or hiring staff. The growth of mechanisms to allow virtual participation by NSF staff in site visits and scientific and other types of professional meetings reduces the burden imposed by frequent travel and enables both scientific and business operations staff to maintain stronger connections with their networks of professional colleagues. These stronger connections to the research, grants management and business operations communities will enable NSF to maintain greater awareness of the evolving research frontier and engagement with the new researchers joining the S&E community.

New Technologies and Knowledge Management

NSF will continue to capitalize on new technologies and emerging data analytics capabilities and pursue vigorously the expansion of its capabilities for analysis and knowledge management. These are needed not only to assess internal operational performance and processes, but also to track and anticipate trends in research and to monitor and oversee progress in the construction of major facilities. NSF program officers and reviewers rely upon the agency's information systems and analytic capabilities to enable the outstanding merit review process that undergirds NSF's global reputation.

Also essential is maintaining a safe and secure physical and cyber environment. NSF relies heavily on IT for all of its processes -- including financial transactions, merit reviews and personnel records -- but IT is also the gateway to communication and interaction with stakeholders in the research community. As trends towards a mobile workforce and remote work continue, IT will only become more important. Work on the Renewing NSF theme of making IT work even better for all will help position NSF to take advantage of advances in information technologies, including AI, automation and the growing availability of shared services.

Strategic Objective 4.1 – Strengthen at Speed and Scale (continued)

Pursue innovative strategies to strengthen and expand the agency's capacity and capabilities.

An Evolving Structure

Periodically, when a new field or type of activity that NSF has nurtured has reached a critical mass, NSF has evolved its structure to better accommodate that growth.[24] This plan coincides with the creation of a new Directorate for Technology, Innovation, and Partnerships (TIP) that will advance research and innovation leading to breakthrough technologies and solutions to national and societal challenges. This directorate will constitute a crosscutting platform that leverages, energizes, and rapidly brings to market and to society the innovations that result from all of NSF's investments. Further, TIP will open up new possibilities for research and education by catalyzing strategic partnerships linking academia, industry, government, philanthropy, investors and civil society to cultivate 21st-century local, regional and national innovation ecosystems. The agency will continue to be ready to adapt its structure and processes as its budget and responsibilities grow.

Administrative Services

To accomplish its mission in research and education while maintaining its outstanding stewardship of taxpayer resources, NSF requires a wide range of operational and administrative services. These include human resource management, procurement, IT, financial management, program management, project management and administrative support.

Built on a commitment to openness and transparency, NSF will follow a strategy of continuous improvement in business processes, financial management and policies and associated infrastructure. This may include the pursuit of partnerships and shared services as a means of promoting excellence and efficiency, as well as innovation in support of a mobile workforce and the use of remote work practices.

NSF will leverage all available authorities to ensure that the contracts, agreements and partnerships it enters allow for innovation, reduce burdens on NSF and its partners, and provide meaningful oversight as the need for operational and administrative services evolve.

TIP will open up new possibilities for research and education by catalyzing strategic partnerships linking academia, industry, government, philanthropy, investors and civil society to cultivate 21st-century local, regional and national innovation ecosystems.

Credit: National Science Foundation

[24] "The National Science Foundation: A Brief History" (1994) https://www.nsf.gov/about/history/nsf50/nsf8816.jsp

Strategic Objective 4.1 – Strengthen at Speed and Scale (continued)

Pursue innovative strategies to strengthen and expand the agency's capacity and capabilities.

Reducing Administrative Burden

Surveys of researchers have identified time preparing proposals and reporting progress on projects as a significant administrative burden. The time researchers spend on developing proposals that are highly rated by reviewers but nevertheless must be declined for lack of funds is a loss of productivity for the research enterprise. NSF will explore a number of remedies to this burden, including increasing award size and duration as budgets permit and pursuing partnerships with non-federal entities interested in collaborating in the support of research and innovation. In addition, NSF will continue its efforts to streamline and simplify reporting.

Risk Management

NSF embraces enterprise risk management. This is applied throughout the life cycle of awards and to the oversight of major facilities, physical and cyber security and other operational processes. NSF is unique in its dynamic organizational structure, which has enabled it to adapt quickly and effectively to transformations in the science, engineering and education landscape. This structure also enables NSF to form effective partnerships across government, academia and industry.

This dynamism and the philosophy of striving for continuous improvement reflect an organization that is constantly learning and evolving. Maintaining resilience in such an environment requires NSF to continue to identify and manage associated risks and opportunities. One example of these risks is a workforce that is in constant transition, with a significant proportion of the scientific staff serving as rotators for one- to four-year terms, coupled with natural attrition and retirement. Information technology systems must be upgraded continually to support evolving business processes as well as necessary security and privacy protections.

NSF will encourage an expansion of the use of methodical risk assessment across the foundation, including identifying, ranking, analyzing, tracking, controlling, accepting, transferring and mitigating risks; developing associated contingency management plans; and planning and implementing strategies that effectively manage and mitigate risk factors. Management challenges identified by the Inspector General will also be an input to this risk management framework. NSF will continue to promote a highly consultative culture, in which appropriate stakeholders are engaged early and throughout risk management processes.

Climate Impact

Recognizing the importance of reducing direct and indirect emissions of greenhouse gases, NSF will examine ways in which it can reduce the impacts of its own operations by, for example, making greater use of virtual meeting technologies to reduce the need for travel by staff and reviewers.

Polar bear mom and cub in the Arctic: Credit: Alfred-Wegener-Institute/Urheber/Fotograf (Creative Commons Attribution 4.0 International)

Assessing Performance and Impact

NSF employs data-driven decision-making. Through an internal evaluation and assessment of current capability and the use of tools such as strategic reviews and the NSF Learning Agenda (see Appendix A.1), NSF will expand its capabilities to assess the performance and impacts of its business processes and programs.

Indicators of progress under this objective could include a measure of the reliability of NSF's information technology resources to ensure that critical information and IT systems are available to support staff and our awardees in their pursuit of NSF's mission.

Strategic Objective 4.2 – Invest in People

Attract, empower and retain a talented and diverse NSF workforce.

One key prerequisite of being able to scale up the pace of discovery and innovation through strengthened NSF investments is a workforce that is engaged, highly capable and diverse. NSF cultivates adaptability and flexibility, furthering the agency's ability to proactively respond to an ever-changing landscape. NSF strives to help prepare a diverse, globally competent STEM national workforce and STEM-literate citizenry, and these goals are also reflected inward. NSF's development of a globally competitive workforce harnesses diverse perspectives that promote innovation and advance the Foundation's mission.

Human Capital Management

To be an effective organization, NSF cultivates capabilities that enable it to be nimble and innovative by using flexible human capital processes that position NSF to readily adapt in a changing scientific and technological environment. From recruitment to development and retention of exceptional administrative and business professionals, scientists and engineers, NSF's investments in human capital, and its commitment to its staff, are rooted in the knowledge that people make scientific exploration and discovery possible.

One component of the Renewing NSF effort involves NSF moving toward a hybrid workforce, which will enable the agency to have a geographically diverse presence, increasing the agency's ability to effectively recruit the best and brightest talent throughout the nation. Another component involves analyzing and assessing NSF's current positions and visualizing future positions. This will strengthen the Foundation's ability to rationalize the many types of position descriptions that NSF uses, standardize career ladders to facilitate greater mobility of staff across the organization and increase the pathways for staff members to advance. It will also ensure that the agency identifies the current and future competencies and skills that are required to harness new technologies and techniques, assess gaps and design a path to ensure employees are poised to meet the future needs of the agency. For example, as skills such as data science and machine learning become more critical, NSF anticipates that the capacity of the agency workforce in these areas will be enhanced through specific hiring and training activities.

Another component of Renewing NSF is NSF's continued implementation of the "Program Management Improvement and Accountability Act" (PMIAA). Leveraging the competency tools and training resources developed for the Major Facility/Acquisition portfolio, NSF will target other significant programs within the broader awards portfolio where program and project management skills are necessary to enable successful program outcomes and enhance agency performance. Training and development plans for NSF staff associated with these programs will incorporate internal resources from the NSF Academy (described below) as well as those being developed by other agencies that are implementing PMIAA.

ATE's AC2 Bio-Link Regional Center: Credit: ATE Centers Impact 2016-2017 (www.atecenters.org.)

NSF uses various hiring authorities to create a balanced workforce of permanent and rotating staff members. The recruitment and promotion processes are strengthened by internal training on the nature of unconscious bias and techniques to mitigate it. Diversity in backgrounds and perspectives is a powerful resource; NSF strives to maintain a workforce that is inclusive at all levels and in all units within the foundation.

Strategic Objective 4.2 – Invest in People (continued)

Attract, empower and retain a talented and diverse NSF workforce.

Training and Professional Development

Through an emphasis on leadership training, coaching and detail assignments, NSF nurtures the development of in-house managerial talent from within its ranks to complement the opportunities provided through external hiring. By recruiting rotators from academia and elsewhere and actively engaging permanent staff in professional society conferences and research community workshops, and through its Independent Research/Development program, NSF maintains its essential, strong connection to the forefront of science, engineering and education research.

NSF leadership fosters an inclusive and engaging workplace for employees by providing employees with an environment that bolsters employee enthusiasm and psychological commitment to the mission and vison of NSF. NSF has an active employee engagement program that is reinforced by a host of work/life programs, which are continuously reviewed to ensure the programs address the challenges faced by employees. To further support an inclusive and engaged workplace, NSF supports a learning culture for all staff by providing a wide array of education and training opportunities for staff members that strengthen the capacity of the Foundation and increase its value to the nation. This support is exemplified in the value placed on employee training and development.

In addition to opportunities for external training, NSF maintains a strong internal resource, the NSF Academy, that continuously develops and disseminates cutting-edge information aimed at enhancing the know-how of the agency's staff. In keeping with its aspiration to be a high-performing organization, NSF provides a vehicle for its employees to learn how to work more efficiently and more creatively, furthering their skills in communication, collaborative work and other tools to enable highly effective teams. This equips employees to meet current and future agency needs and to be utilized to their fullest potential. NSF provides its managers with the requisite toolkit for managing effectively, offering opportunities to learn and enhance skills that are tailored to new and experienced managers, respectively.

Employee Engagement

The high performance of NSF's workforce is crucial to the fulfillment of the agency's mission. NSF rewards exemplary performance through a variety of employee recognition programs.

NSF promotes strong internal and external communications, ensuring staff and community stakeholders are both engaged in and informed about organizational change.

NSF employees learn and grow in important ways that contribute to the organization as a whole and enable NSF to function as a model federal agency. NSF leadership works hard to make NSF one of the best places to work in the federal government. To that end, the information gained from the Federal Employee Viewpoint Survey (FEVS) and other employee feedback mechanisms is highly valued by leadership. Expectations for maintaining an inclusive and engaging workplace are held high by leadership, as demonstrated by the time and resources devoted to maintaining NSF's high relative rankings as compared to other federal agencies.

Indicators of progress under this objective could include a measure tracking NSF's implementation of its Human Capital Operating Plan, which identifies the actions the agency will take to achieve its human capital goals.

Great American Solar Eclipse: Credit: Rob Margetta, NSF

Closing

NSF will continue to live up to its reputation as an efficient, effective, agile and forward-looking organization, while scaling up its operations so that it can continue to meet the national need for a strong and vibrant research and STEM training enterprise.

VII AGENCY PRIORITY GOAL

This Plan includes the following Agency Priority Goal (APG) which aligns with Strategic Objective 1.1, **Increase the involvement of communities underrepresented in STEM and enhance capacity throughout the nation.** While APGs cover a two-year timespan, the underlying theme of closing talent gaps in STEM by describing, reducing and dismantling barriers to full participation will likely maintain its priority status throughout the four-year life of this Strategic Plan.

More information on NSF's agency priority goal, as well as the APGs from other federal agencies will be published and updated on performance.gov.

IMPACT:

Improve representation in the scientific enterprise by making changes that will lead to an increase in proposal submissions from underrepresented and underserved applicants and communities.

NSF Headquarters in Alexandria, VA.: Credit: NSF

ACHIEVEMENT:

By September 30, 2023, NSF will increase both the number and proportion of proposals received from underrepresented and underserved 1) investigators and 2) institutions by 10 percent over the FY 2020 baselines.

VIII EXAMPLES OF LONG-TERM PERFORMANCE GOALS

NSF's Annual Performance Plan rests on a set of specific performance goals. Each of these is associated with one or more strategic objectives in the strategic plan and is reviewed annually in strategic reviews or quarterly performance reviews. These performance goals enable strategic monitoring and oversight of progress being made on the Foundation's most important activities. As such, the annual goals provide indicators of progress towards longer-term goals for NSF's priority program investments, research infrastructure investments and key management initiatives, as well as the satisfaction of proposers and reviewers. In addition to the Agency Priority Goal described above, brief descriptions of four examples of long-term performance goals are included here.

Ensure that key NSF-wide program investments are implemented and on track.	Each year, NSF highlights cross-agency investments in the NSF-Wide Investments chapter of its Budget Request to Congress. Although the overall impact of these investments will not be realized for many years, tracking near-term indicators of progress can help the agency make formative changes or course corrections. This has been a goal since FY 2014. The list of monitored programs evolves based on investment priorities for a particular year.
Ensure program integrity and responsible stewardship of major research facilities and infrastructure.	NSF monitors the performance of major facility projects by monitoring cost and schedule variances using Earned Value, a standard measure of performance for construction projects.
Inform applicants of funding decisions in a timely manner.	The time it takes NSF to process proposals – the amount of time that passes between receipt of a proposal and notification to the principal investigator about the funding decision -- is important for principal investigators. Too long a time delays the progress of research, but too much haste may weaken the merit review process by forcing premature decisions. The optimal processing time depends on several factors, including the complexity of the proposed activity, the need for co-review by more than one program, the need for site review, infrastructure requirements and the funding requested. Large, complex proposals require more time for review to ensure that taxpayer dollars are invested wisely.
Continue to improve user interactions with NSF's IT systems.	NSF leverages state-of-the-art IT solutions to develop flexible tools and provide continual improvement of current services, streamlining and simplifying the interactions that staff and the research community have with NSF's digital systems. This also streamlines administrative activities for both internal and external users and enables the agency to carry out its mission more effectively. Annual performance goals contribute to this long-term goal by focusing on key factors and advances such as maintaining system availability, consolidating points of access and augmenting functionality.

Investment Portfolio

NSF creates a high-impact, forward-leaning investment portfolio. NSF receives about 43,000 grant proposals each year and 12,000 graduate research fellowship applications in virtually all areas of science, engineering and education research. Since the agency can fund only a fraction of the meritorious proposals and applications received, NSF uses a strategy of maintaining a balanced, geographically distributed portfolio of funded projects that: supports different approaches to significant research questions; addresses societal needs; builds capacity in new and promising research areas; supports high-risk proposals with potential for transformative advances in a field; integrates research and education; and broadens participation in STEM research.

Investment Areas

NSF works with the research community and other stakeholders to identify key areas for future investment. These may reflect emerging opportunities of great promise, address pressing challenges or respond to critical national needs. They may involve NSF-wide activities and require sustained levels of investment over many years, or they may be more narrowly focused and change from year to year as promising opportunities arise.

NSF receives input on the identification and prioritization of investment areas from many sources. It uses a variety of mechanisms to envision the future of S&E. These include the NSB, the National Academies, advisory committees, workshops, calls for white papers and other community engagement activities.

Potential investment areas are evaluated against considerations that include: alignment with NSF's mission; budget; potential for impact; urgency and readiness; the integration of research with education and strengthening of the connections between learning and inquiry; the potential to broaden participation in S&E; and collaboration and partnership opportunities.

Awards

Proposals for individual research projects are evaluated using the merit review criteria provided by the NSB. NSF strives to maximize the collective impact of these projects by using the following strategies:

- Maintaining NSF's high-quality merit review process, while seeking continuous improvement.
- Partnering with other science sponsors and professional organizations.
- Welcoming interdisciplinary proposals and proposals that pursue novel approaches.
- Using, where appropriate, quantitative or other evidence-based evaluation of programs and investment areas.
- Maintaining up-to-date digital tools and business systems.
- Complementing the expertise of NSF's permanent staff with the knowledge and experience of leading researchers and educators on temporary assignment to NSF.

Agency Operations

NSF will increase efficiency and effectiveness by:

- Harnessing new information technologies and leveraging state-of-the-art IT solutions from the private and public sectors.
- Continuing to take advantage of cloud resources and shared services that offer the potential for new efficiencies.
- Exploiting new developments in software to improve the implementation of core processes such as merit review and financial management.
- Expanding public and private partnerships.
- Streamlining interagency activities, such as by simplifying the joint analysis of proposals and awards across federal agencies.
- Using alternate funding delivery models beyond those that have been used traditionally by NSF.
- Establishing new partnerships in research areas of special emphasis.
- Simplifying programs and processes, for example by reducing the use of deadlines and expanding opportunities for proposals unconstrained by topic area.
- Augmenting the skills of the workforce with those needed to function effectively in more integrated, crosscutting settings and enhance program and project management.
- Continuing to enhance a culture of diversity, equity and inclusion through training and recruitment.

X STAKEHOLDER ENGAGEMENT

The development of the updated strategic plan began in September 2020 and included gathering suggestions from numerous stakeholders about how the current strategic plan should evolve. That process is summarized below.

1	From October 2020 to February 2021, NSF invited people inside and outside the foundation to provide comments on the existing strategic plan. This included discussions among NSF staff, with the NSB, with external advisory committees, and with professional societies and other organizations.
2	Through an online portal, NSF received over 100 public comments between January and April 2021.
3	NSF engaged with the Committee on Strategy of the NSB in the development of the initial strategic framework, the preliminary draft plan and the final draft plan in a series of virtual meetings from December 2020 to November 2021.
4	A high-level summary of the revised strategic goals and objectives was shared with OMB in June 2021.
5	A preliminary draft of the strategic plan incorporated suggestions received through the public portal, from advisory committees, from the National Science Board and from NSF staff members. It was submitted to OMB in September 2021.
6	After receiving feedback on the preliminary draft strategic plan from OMB, NSF shared the preliminary draft with Congress.
7	Additional feedback was provided by the NSB in November 2021.
8	The final version of the strategic plan is being provided to Congress in March 2022.

Appendix A.1. Learning Agenda

The learning agenda contains two levels of questions:

1. **GUIDING "high-level" questions (aligned with goals).**
2. **SPECIFIC questions that each indicate a priority to be tackled through studies described in the learning agenda.**

Goal 1. **How can NSF grow STEM talent and opportunities for all Americans most equitably?**	FY22-1. How can NSF help increase the participation of underrepresented groups in the STEM workforce? FY22-2. In what ways did the coronavirus COVID-19 pandemic influence the participation of different groups in the NSF portfolio of programs and activities? FY22-3. How can NSF help reduce and ultimately eliminate harassment in federally-funded research settings? FY22-4. How could the data system developed for the Research Experiences for Undergraduates (REU) Sites program be leveraged to improve prospective monitoring of characteristics of participants in research experiences supported by other NSF programs and study the impact of research experiences on STEM outcomes, such as educational attainment?
Goal 2. **How can NSF fuel transformative discoveries most effectively?**	FY22-5. What are the characteristics of NSF's portfolio on climate change, and to what extent might this portfolio advance NSF's goals of equity, discovery and impact? FY22-6. How do EPSCoR program funding strategies (infrastructure, co-funding and outreach) contribute to increasing academic competitiveness across jurisdictions?
Goal 3. **How can NSF mobilize knowledge most effectively to impact society?**	FY22-7. What are the benefits of receiving an award from a program supported by a partnership? How do these differ from benefits associated with awards from programs not supported by a partnership? What outputs and outcomes are associated with partnership programs? To what extent can these be attributed to the partnership programs? What improvements could make partnership programs more effective or easier to implement? FY22-8. What can be learned from the Convergence Accelerator's innovative selection process that may inform improvements in how the agency identifies and selects projects with high potential to advance ideas from concepts to deliverables to industry and other partners? In what ways does the Convergence Accelerator innovation training contribute to the emergence of new capacities among participating researchers to meet pressing societal needs?
Goal 4. **How can NSF excel in stewarding and realizing its vision?**	FY22-9. What are the characteristics of proposals evaluated through the merit review process? Are these characteristics (of individual investigators, teams, institutions or proposed projects) associated with different review or funding outcomes? FY22-10. What outcomes are associated with the adoption of a no-deadlines proposal submission process?

Appendix A.1. Learning Agenda (continued)

Mapping Between Learning Agenda Questions and Strategic Objectives

LA Question	SG 1 - Empower		SG 2 - Discover		SG 3 - Impact		SG 4 - Excel	
	SO 1.1	SO 1.2	SO 2.1	SO 2.2	SO 3.1	SO 3.2	SO 4.1	SO 4.2
1	✓	✓	✓		✓			
2	✓							
3	✓	✓	✓	✓	✓	✓	✓	✓
4	✓	✓		✓				
5	✓		✓		✓	✓		
6	✓	✓	✓	✓				
7	✓	✓	✓	✓	✓	✓		
8			✓	✓	✓	✓		
9	✓	✓	✓	✓	✓	✓	✓	
10	✓		✓				✓	

Appendix A.2. Capacity Assessment

In 2021, NSF developed an integrated assessment of data maturity and capacity to generate and use evidence to inform decision-making. NSF's Capacity Assessment complies with the "Foundations for Evidence-Based Policymaking Act of 2018" (Evidence Act) and the Federal Data Strategy. Findings will help guide improvements to bolster NSF's capacity to produce useful evidence to support decision-making.

NSF's Capacity Assessment includes two components — an organizational assessment and an analysis of NSF's inventory of ongoing evidence-building activities.

The organizational assessment examined four foundational themes:

1	2	3	4
Building a culture that values data and promotes public use;	Governing, managing and protecting data;	Promoting efficient and appropriate data use; and	Generating evidence and supporting evidence generation and use.

The findings are based on an analysis of data collected through focus groups across NSF offices and directorates and a review of supporting artifacts (documents that demonstrate existing policies, processes, or practices).

Findings from the organizational assessment showed that NSF has a culture that values data and evidence, with leadership setting a strong tone regarding the Foundation's commitment to evidence-based decision-making. On average, NSF operates in the middle stages of data and evidence maturity for each foundational theme assessed (data culture, data governance, data use and evidence generation and use). Variation in maturity across directorates and offices revealed pockets of excellence and innovation, with some NSF organizations operating at high levels of maturity. Highly mature efforts may provide models to adopt or build on in developing an agency-wide strategy that leverages NSF's culture of evidence in support of consistent practices and procedures.

Analysis of evidence-building activities (namely, evaluation, research and analysis) showed that, in FY 2021, NSF was pursuing over three dozen formal activities. Most of these activities were conducted in support of the agency's mission, benefitted stakeholders across the entire agency, addressed a variety of questions to meet a wide range of needs and relied on methodologies (from rigorous program evaluations to exploratory policy analysis) that are well aligned with the research questions. Findings from the analysis of ongoing studies aligned with those of the organizational assessment, underscored the value that NSF places on evidence, and identified opportunities for targeted improvements.

The main finding of the analyses presented in the capacity assessment was that NSF values data and has a strong culture of using evidence to inform decisions. Further embracing and strengthening, rather than changing, NSF culture is recommended. In the period covered by this strategic plan, NSF will continue to mature its data and evidence capabilities.

Appendix A.3. Contributing Programs

The "GPRA Modernization Act of 2010" requires each agency to develop an inventory of its programs. NSF categorizes its federal programs by initial topic area of investment. This approach mirrors its budget structure and the programs presented here are consistent with the program activity lines presented in the President's Budget Appendix. This aligns with the way the agency executes its budget and is complementary with the expectations of external stakeholders. The ordering of this list follows the budget structure. Programs funded through the Research and Related Activities and the Education and Human Resources accounts are listed first, followed by Major Research Equipment and Facilities Construction, Agency Operations and Award Management, the NSB, and the Office of Inspector General.

List of NSF Strategic Goals and Objectives 2022 – 2026

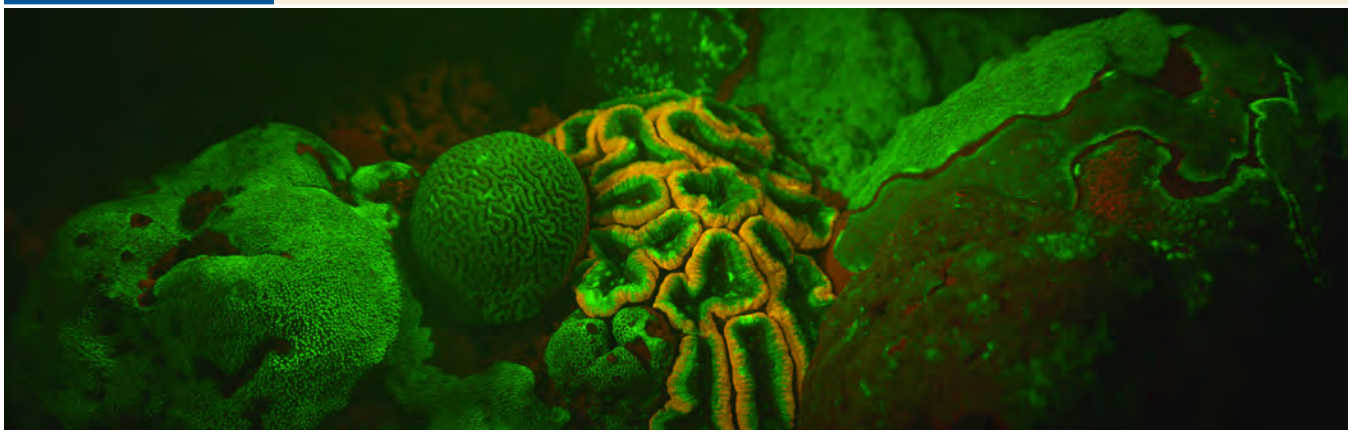
Strategic Goal 1	**SG1. Empower STEM talent to fully participate in science and engineering.** Strategic Objective 1.1 (SO1.1) – Ensure accessibility and inclusivity: Increase the involvement of communities underrepresented in STEM and enhance capacity throughout the nation. Strategic Objective 1.2 (SO1.2) – Unleash STEM talent for America: Grow a diverse STEM workforce to advance the progress of science and technology.
Strategic Goal 2	**SG2. Create new knowledge about our universe, our world and ourselves.** Strategic Objective 2.1 (SO2.1) – Advance the frontiers of research: Accelerate discovery through strategic investments in ideas, people and infrastructure. Strategic Objective 2.2 (SO2.2) – Enhance research capability: Advance the state of the art in research practice.
Strategic Goal 3	**SG3. Benefit society by translating knowledge into solutions.** Strategic Objective 3.1 (SO3.1) – Deliver benefits from research: Advance research and accelerate innovation that addresses societal challenges. Strategic Objective 3.2 (SO3.2) – Lead globally: Cultivate a global science and engineering community based on shared values and strategic cooperation.
Strategic Goal 4	**SG4. Excel at NSF operations and management.** Strategic Objective 4.1 (SO4.1) – Strengthen at speed and scale: Pursue innovative strategies to strengthen and expand the agency's capacity and capabilities. Strategic Objective 4.2 (SO4.2) – Invest in people: Attract, empower and retain a talented and diverse NSF workforce.

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Biological Sciences (BIO)

Description	The BIO Directorate promotes the progress of the biological sciences, increases scientific knowledge and enhances understanding of major problems confronting the nation. The directorate includes support of research project grants in the following disciplines: molecular and cellular biosciences; integrative organismal biology; environmental biology; and biological infrastructure. Support is also provided for the purchase of multi-user scientific equipment and instrument development, and for research workshops, symposia and conferences. In addition, awards are made to support graduate student research and postdoctoral fellowships across biological sciences, including groups underrepresented in all areas of research supported by the biological sciences. The divisions within the BIO Directorate are: • Biological Infrastructure (DBI). • Environmental Biology (DEB). • Emerging Frontiers (EF). • Integrative Organismal Systems (IOS). • Molecular and Cellular Biosciences (MCB). Current information about the BIO Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.



Fluorescent coral: Credit: David Gruber, Baruch College, City University of New York

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Computer and Information Science and Engineering (CISE)

Description	The CISE Directorate supports investigator-initiated research and education in all areas of computing, communications and information science and engineering. It advances the development and use of research cyberinfrastructure to enable and accelerate discovery and innovation across all science and engineering disciplines and contributes to the education and training of future generations of researchers, practitioners, and users of computing, communications and information science and engineering, as well as research cyberinfrastructure. The divisions and offices within the CISE Directorate are: • Office of Advanced Cyberinfrastructure (OAC). • Computing and Communication Foundations (CCF). • Computer and Network Systems (CNS). • Information & Intelligent Systems (IIS). • Information Technology Research (ITR). Current information about the CISE Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.

Network interconnect cabling on Frontera's compute nodes: Credit: TACC

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Engineering (ENG)

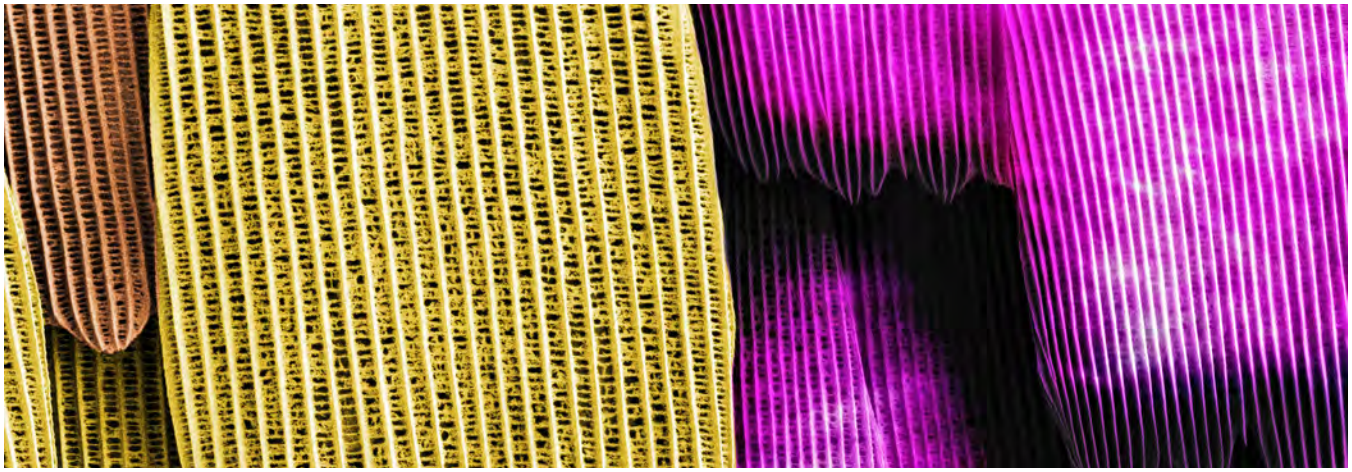
Description	The ENG Directorate improves the quality of life and the economic strength of the nation by fostering innovation, creativity and excellence in engineering education and research. It invests in the creation of new engineering knowledge and the development of human capital; makes critical investments to enable an intelligent, agile and adaptable physical infrastructure for engineering education and research; improves the quality and effectiveness of engineering education and research through the integration and systemic reform of these processes; and enables knowledge transfer among diverse constituencies and communities. Areas of research include: tissue engineering; metabolic pathway engineering; bioinformatics; protein drug processing; fluid flow; combustion; heat transfer; fuel cells; sensors; integrated modeling of the behavior of materials and structures; civil infrastructure; structures and mechanical systems; engineering in geologic materials; reducing risks of natural and technological hazards; enterprise-level integration technologies; innovative design strategies; manufacturing processes and materials; production systems; microelectronic, nanoelectronic, micromagnetic, photonic and electromechanical devices and their integration into circuits and microsystems; design and analysis of systems and the convergence of control, communications and computation; Engineering Research Centers; Industry/University Cooperative Research Centers; engineering education; human resources development; crosscutting activities; and special studies and analyses. Support is also provided for undergraduate student research, graduate research fellowships, Broadening Participation in Engineering (BPE), research equipment and instrumentation and Grant Opportunities for Academic Liaison with Industry (GOALI). • The divisions within the ENG Directorate are: • Chemical, Bioengineering, Environmental, and Transport Systems (CBET). • Civil, Mechanical and Manufacturing Innovation (CMMI). • Electrical, Communications and Cyber Systems (ECCS). • Engineering Education and Centers (EEC). • Emerging Frontiers in Research and Innovation (EFRI). • Industrial Innovation and Partnerships (IIP). Current information about the ENG Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Geosciences (GEO)

Description	The GEO Directorate strengthens and enhances the national scientific enterprise through the expansion of fundamental knowledge and increased understanding of the integrated Earth system. It supports basic research in the atmospheric, earth and ocean sciences. Objectives include the discovery of new knowledge of the atmosphere from the sun to the Earth's surface over the entire spectrum of physical and chemical phenomena; a better understanding of the physical, chemical and biological character of the Earth and the processes that govern its evolution; and increased insight into the world's oceans, including their composition, structure, behavior and tectonics. Support is also provided for undergraduate student research, graduate and postdoctoral fellowships, facility enhancement, instrumentation and laboratory equipment, and for research opportunities for women, minority scientists and engineers and those with disabilities. The divisions within the GEO Directorate are: • Atmospheric and Geospace Sciences (AGS). • Earth Sciences (EAR). • Integrative and Collaborative Education and Research (ICER). • Ocean Sciences (OCE). Current information about the GEO Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.



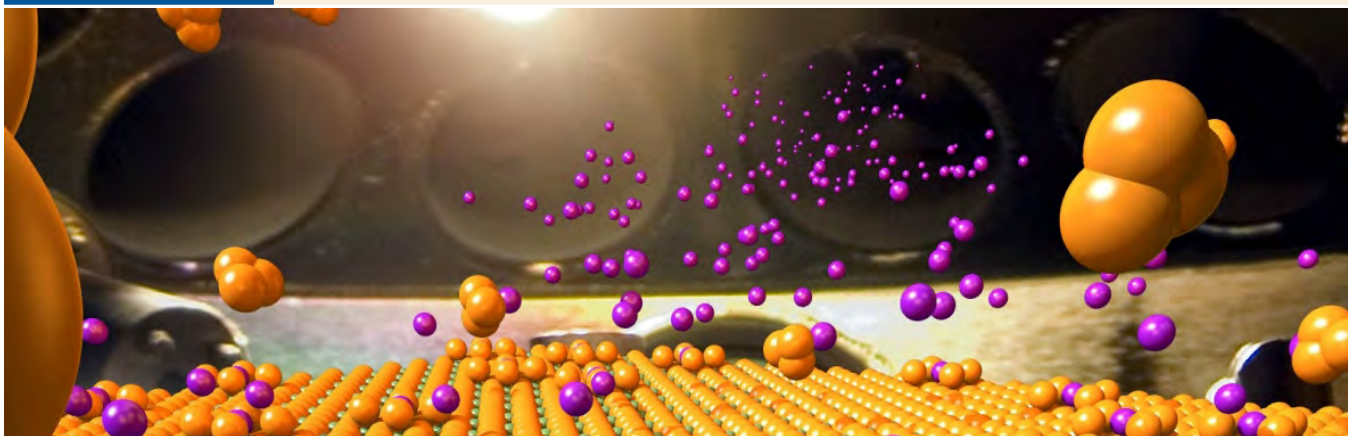
Microscopic view of sulphur butterfly wing featuring UV-iridescence on scales: Credit: Arnaud Martin and Anna Ren/The George Washington University

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Mathematical and Physical Sciences (MPS)

Description	The MPS Directorate promotes the progress of the mathematical and physical sciences. MPS includes support of research project grants in the following disciplines: astronomical sciences, chemistry, materials research, mathematical sciences and physics. It also supports symposia and conferences in these disciplines. Basic research in multidisciplinary areas related to these disciplines is especially encouraged. Support is also provided for: state-of-the-art user facilities in astronomy, physics and many areas of materials science; Science and Technology Centers; institutes; undergraduate student research; faculty enhancement; curriculum development; instrumentation; laboratory improvement; and for research opportunities for women, minority scientists and engineers, and those with disabilities. The divisions and offices within the MPS Directorate are: • Astronomical Sciences (AST). • Chemistry (CHE). • Materials Research (DMR). • Mathematical Sciences (DMS). • Physics (PHY). • Office of Multidisciplinary Activities (OMA). Current information about the MPS Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.



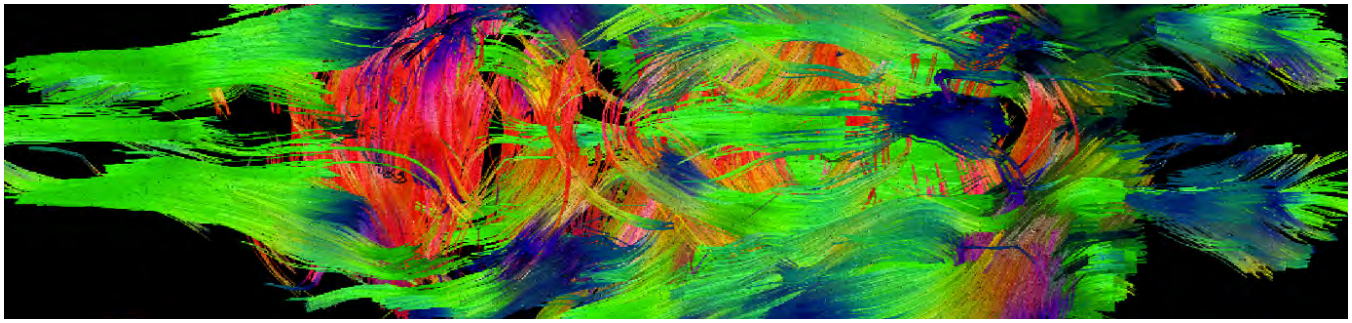
Glimpse inside custom-designed molecular beam epitaxy system: Credit: Courtesy of Brookhaven National Laboratory

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Social, Behavioral, and Economic Sciences (SBE)

Description	The SBE Directorate promotes basic research and education in the social, behavioral and economic sciences and monitors the resources invested in science and engineering in the U.S. Supported activities include research and education in the following disciplines: anthropological and geographic sciences; cognitive, psychological, learning, developmental and language sciences; economics, decision risk and management sciences; sociology; security and preparedness; accountable institutions and behavior; innovation and organizational change; measurement methods and statistics; law and science; and science and technology studies. Other SBE grants build infrastructure; develop methods; support center-scale investments; seek to understand the conduct of ethical and responsible research; and fund research workshops, symposia and conferences. Educational activities include awards to improve the quality of doctoral dissertations in the behavioral and social sciences; grants for graduate traineeships and postdoctoral fellowships; and grants to promote K-12 education in the SBE sciences. The directorate also funds studies of scientists and engineers, R&D funding and expenditures, and educational attainment in science, mathematics and engineering. The divisions and offices within the SBE Directorate are: • Social and Economic Sciences (SES). • Behavioral and Cognitive Sciences (BCS). • Office of Multidisciplinary Activities (SMA). • National Center for Science and Engineering Statistics (NCSES). Current information about the SBE Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.



Streamlines in mouse brain indicating direction of white matter tracts: Credit: Sean Foxley, Department of Radiology, University of Chicago

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Technology, Innovation, and Partnerships (TIP)

Description	The TIP Directorate supports science and engineering research and innovation leading to breakthrough technologies as well as solutions to national and societal challenges, sustaining and enhancing U.S. competitiveness on a global stage. TIP accelerates the translation of fundamental discoveries from lab to market, advancing the U.S. economy and creates education pathways for Americans to pursue new, high-wage, good-quality jobs, supporting a diverse workforce of researchers, practitioners and entrepreneurs. The divisions and offices within the TIP Directorate are: • Innovation Ecosystems (IE). • Partnerships Office (PO). • Technology Frontiers (TF). • Translational Impact (TI). Current information about the TIP Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2; SO4.1; SO4.2.

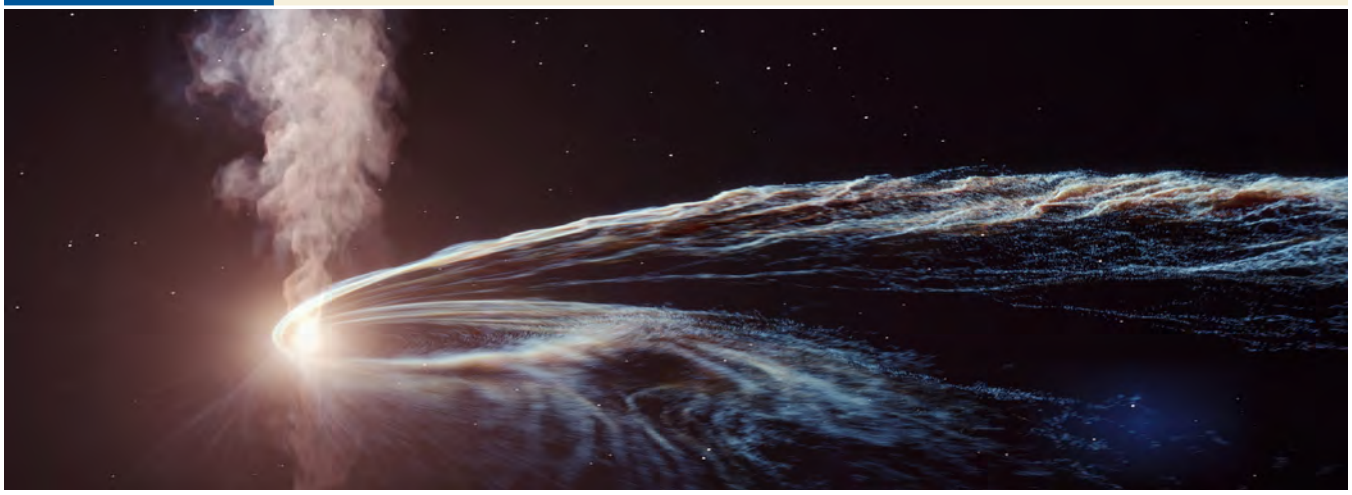
Credit: National Science Foundation

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Office of International Science and Engineering (OISE)

Description	OISE enables the U.S. to maintain its leadership within the global scientific community by strengthening international partnerships to advance scientific discovery; promotes research excellence through international collaboration; and develops a diverse, globally engaged U.S. science and engineering workforce by providing U.S. students and faculty with international research and education experiences. OISE programs include support of international research and education projects that are innovative and catalytic. OISE programs complement and enhance the Foundation's research and education portfolio to overcome barriers involved in international collaboration. Grants are made in all the disciplinary fields supported by NSF. Support is provided for international collaborative research; research workshops and planning visits; activities that will develop the next generation of U.S. scientists and engineers, such as graduate traineeships and postdoctoral fellowships; special opportunities for junior faculty for research support and dissertation enhancements; and for U.S. government support to key multilateral organizations. Support is provided for undergraduate student international research and education experiences and for research opportunities for women, minorities and scientists and engineers with disabilities. Current information about OISE can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.



Debris from a star destroyed by supermassive black hole are flung into space: Credit: DESY, Science Communication Lab

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Office of Polar Programs (OPP)

Description	OPP strengthens and enhances the national scientific enterprise through the expansion of fundamental knowledge and increased understanding of the polar regions. It encourages and supports basic research that is best conducted in or can only be conducted in the Arctic and Antarctic. Research areas include: solid earth; glacial and sea ice; terrestrial ecosystems; the oceans; the atmosphere; geospace science; astronomy and astrophysics; social science; and others. Major objectives include understanding the natural phenomena and processes in the Antarctic and Arctic regions and their role in global systems. It supports the development and training of new investigators in polar regions research, supports innovative research in emerging areas, encourages interdisciplinary research, fosters activities that create broader impacts for science and society and increases the participation of under-represented groups. Support is also provided for undergraduate student research, facility enhancement, instrumentation, laboratory equipment and research opportunities for women, minority scientists and engineers and those with disabilities. The U.S. Antarctic Program provides critical support that enables research and scientific observations in the Antarctic sponsored by NASA, NOAA, USGS, DOE and DOD (Comprehensive Test Ban Treaty monitoring) as well as NSF. Current information about OPP can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.

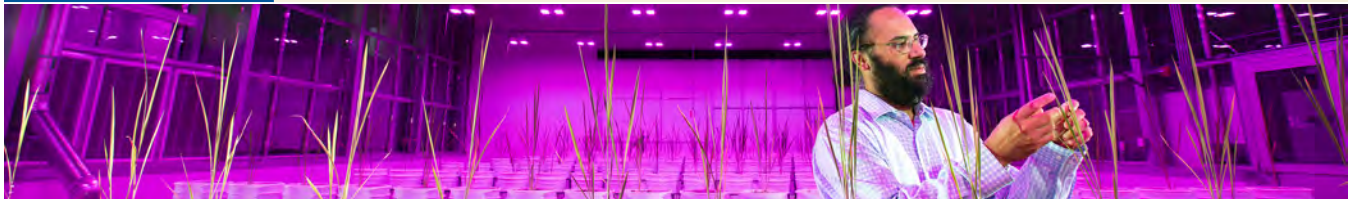
Waves produced by iceberg calving near terminus of Hansbreen glacier: Credit: Oskar Glowacki, Scripps Institution of Oceanography, UC San Diego

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Office of Integrative Activities (OIA)

Description	OIA incubates new ideas and communities, supports innovation in research and NSF's own processes and promotes integration across research and education domains. Support is provided to develop human and infrastructure capacity critical to the U.S. science and engineering enterprise, to catalyze new crosscutting programs, to expand NSF's capability to gather and use evidence about the progress and impacts of its programs, for prestigious honorary award programs and professional internships for aspiring scientists and engineers and for policy and programmatic analysis for the NSF Director, Deputy Director and Chief Operating Officer. The subactivities housed within OIA include: • Equity and Compliance in Research • Evaluation and Assessment Capability. • Established Program to Stimulate Competitive Research. • Facility Operation Transition. • Growing Convergence Research. • Growing Research Access for Nationally Transformative Equity and Diversity. • HBCU Excellence in Research. • Major Research Instrumentation. • Mid-scale Research Infrastructure. • Modeling and Forecasting. • Planning and Policy Support. • Research Investment Communications. • Research Security Strategy and Policy. • Science and Technology Centers. • Science and Technology Policy Institute. Current information about OIA can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.



Improving crop resilience for global food security: Credit: University Communication / University of Nebraska-Lincoln

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

United States Arctic Research Commission (USARC)

USARC is an independent agency that is included in NSF's program inventory but not covered by the NSF strategic plan.

Description	USARC promotes Arctic research and recommends national Arctic research policies to guide federal agencies in developing and implementing their research programs in the Arctic region. Current information about USARC can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	N/A.
Supported Strategic Objectives	N/A.

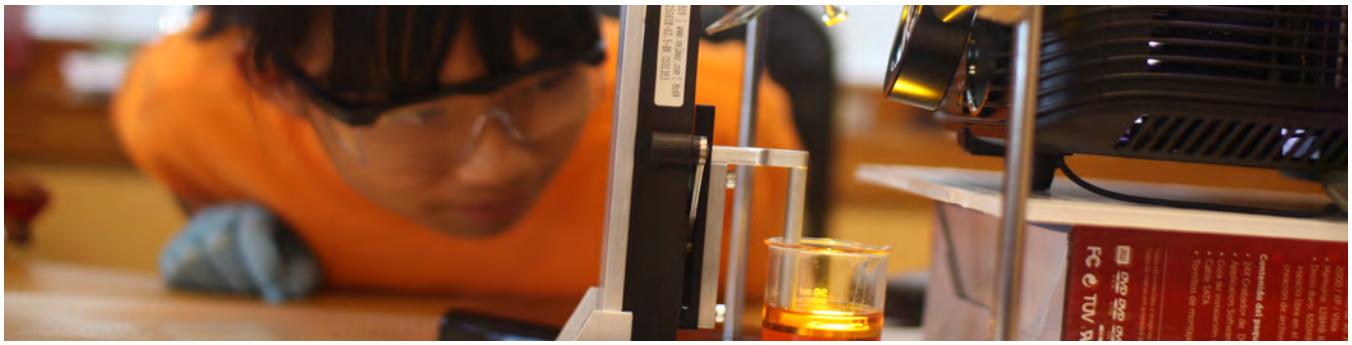
Icebreaker during research expedition: Credit: Zhangxian Ouyang, University of Delaware

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Directorate for Education and Human Resources (EHR)

Description	The EHR Directorate sponsors programs that support the development of models and strategies for providing all students with access to high-quality STEM education, and research about those models and strategies. In addition, EHR supports scholarships and fellowships for STEM students. The portfolio of EHR programs in STEM education comprises efforts spanning pre-K to 12, undergraduate, graduate and postdoctoral levels, as well as informal education and life-long learning. Long-term goals include: supporting infrastructure and institutional capacity building that will enable development of high-quality educational experiences for all students; ensuring that educational pathways yield a well-educated and diverse corps of individuals for the highly technical workplace, the professional STEM community and society; developing a cadre of professionally-educated and well-trained teachers and faculty; and providing the research necessary to inform and improve educational practice. Programs include: R&D support for improving STEM learning and learning environments, including learning technologies in both formal and informal learning settings; and STEM workforce development, including the development of teachers; and broadening participation. The divisions within the EHR Directorate are: • Research on Learning in Formal and Informal Settings (DRL). • Graduate Education (DGE). • Human Resource Development (HRD). • Undergraduate Education (DUE). Current information about the EHR Directorate can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.



Students Create 3-D Objects in the Classroom: Credit: Joe Muskin, University of Illinois

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

Major Research Equipment and Facilities Construction (MREFC)

Description	MREFC activity supports the acquisition, construction and commissioning of unique national research platforms and major research facilities and equipment. Performance of each construction project is measured against an established baseline at regular intervals and at major milestones. Current information about MREFC can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO2.1; SO2.2; SO3.2; SO4.1.

Agency Operations and Award Management (AOAM)

Description	AOAM funds NSF's scientific, professional and administrative workforce; the physical and technological infrastructure necessary for a productive, safe and secure work environment; and the essential business operations critical to NSF's administrative processes. Current information about AOAM can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.

Appendix A.3. Contributing Programs (continued)

List of Directorates and Major Offices

National Science Board (NSB)

Description	The NSB provides policy-making and related responsibilities for NSF and provides guidance on significant national policy issues in S&E research and education, as required by law. Current information about the NSB can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG1. Empower STEM talent to fully participate in science and engineering. SG2. Create new knowledge about our universe, our world and ourselves. SG3. Benefit society by translating knowledge into solutions. SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO1.1; SO1.2; SO2.1; SO2.2; SO3.1; SO3.2 ; SO4.1; SO4.2.

Office of Inspector General (OIG)

Description	OIG provides agency-wide audit and investigative functions to identify and correct management and administrative deficiencies that create conditions for existing or potential instances of fraud, waste and mismanagement, consistent with the "Inspector General Act of 1978," as amended (5 U.S.C. App. 3). Current information about OIG can be found at http://nsf.gov/about/budget/.
Supported Strategic Goals	SG4. Excel at NSF operations and management.
Supported Strategic Objectives	SO4.1.

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