NSF'S RESEARCH PORTFOLIO: THE DISCOVERY ENGINE

Description and Rationale

NSF funds research on vital problems and challenges that serve to advance science to benefit the Nation. NSF's support for innovative research helps to improve quality of life, enhance national security, and fuel American leadership in a wide range of technological and industrial sectors. NSF supports all fields of science and engineering, starts and fuels dynamic collaborations, supports innovation in all areas of STEM education, and broadens opportunity and participation in America's science and engineering enterprise. Because NSF does all this simultaneously, it can integrate these approaches in its research portfolio where and when it is needed.

NSF's research portfolio, through which both research and education opportunities are funded, is the endeavor for which the agency is best known. This research portfolio refers broadly to foundational research whose topics and goals are identified and driven by research communities and individual investigators. Resulting disciplinary or interdisciplinary proposals are submitted to a rigorous peer-review process through which NSF identifies and supports groundbreaking research concepts that are then implemented by tens of thousands of students and researchers in nearly 2,000 research institutions.

Over the past seven decades, NSF's research portfolio—the **Discovery Engine**—has funded research and researchers, innovations and innovators, and world-class research infrastructure that have helped to transform America. While it is foundational in nature, it produces strong societal dividends in diverse areas and on many timescales. NSF investments have produced science and technology with deeply impactful and visible results. The Internet, Google, Qualcomm, 3D printing, the economic theory underpinning spectrum auctioning and kidney exchanges, and the polymerase chain reaction (PCR) testing technique that is critical in the fight against COVID-19 were all supported NSF investments.[1] Of Nobel Prize winners, 253 have received funding from NSF. For Computing's analog to the Nobel Prize, the Turing Award, nearly two-thirds of all recipients (43 out of 71) have received funding from NSF.

NSF is looking ahead, seeking to build on past successes in supporting foundational discoveries, impactful technologies, and tomorrow's emerging industries. Across all STEM areas, and comprising both research and education, NSF is supporting potentially groundbreaking work in climate change adaptation and mitigation, artificial intelligence, quantum information science, advanced manufacturing, advanced wireless, biotechnology, new educational technologies, stronger infrastructure, bias reduction, greater equity, better jobs, and much more.

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[1] National Academies. Information Technology Innovation: Resurgence, Confluence, and Continuing Impact. www.nap.edu/read/25961/chapter/1

Goal of Investment

NSF's research portfolio advances science and engineering discovery in many ways, and notably overlaps with key Administration priorities with investments in Climate and Clean Energy, Equity for Underserved Communities, and Emerging Industries. At the FY 2023 Request level, NSF's research portfolio will promote American leadership in these and other vital areas while laying the foundation for future advances for decades to come. NSF will pursue these goals in three complementary ways:

- **High-Value Strategic Investments in Research.** These investments seize new opportunities for making substantial advancements. They combine the potential for meaningful breakthroughs now with dynamic opportunities for long-term innovation. These investments prompt and accelerate the formation of new industries and evolve in response to urgent national needs.

- **Integrating Research and Education.** In NSF's research portfolio, research and education inform and strengthen one another, creating a feedback loop that advances science and engineering while building a workforce fluent in state-of-the-art science and technology topics. NSF programs are based on the premise that interweaving research and education creates opportunity at greater scale than either activity on its own. Integrating research and education strengthens American leadership in a wide range of scientific and technological domains.

- **Broadening Opportunity and Participation in STEM.** Every demographic and socioeconomic group in every geographic region of the country has talent to contribute. NSF seeks to inspire, motivate, and support more people to contribute to, and benefit from, America's science and engineering enterprise. For NSF, broadening participation is both an emphasis of specific programs, as indicated in the portion of this document that focuses on equity, and is increasingly integrated into all research activities.

Potential for Impact, Urgency, and Readiness

America faces a time of great challenges and greater opportunities. We seek to improve quality of life for everyone. We seek to strengthen communities and create well-paying jobs. We seek to lead the world in innovation and to translate that innovation to empower an America that is more secure, more resilient, more sustainable, and more just. These are the principles by which NSF's research portfolio operates, and the Administration's policy framework further strengthens NSF's resolve to promote these ideals in the groundbreaking work that NSF funds.

Building on a Groundbreaking Strategy
For decades, NSF has helped fuel American leadership in vital areas of science and engineering and in the economic, environmental, social, and military domains that science can advance.

Because of the way in which NSF's component parts work together and coordinate, the NSF approach is capable of finding and supporting groundbreaking ideas. When NSF receives outstanding proposals that do not fit squarely into a single academic discipline, different parts of NSF work together to evaluate and support them.

NSF has broad reach and deep relationships with many academic communities, representing approximately 24 percent of the total federal budget for basic research conducted at U.S. colleges and

universities. In many fields such as mathematics, computer science, and the social sciences, NSF is the largest source of federal backing. These relationships and the all-of-STEM reach of its research portfolio give NSF the ability to draw, identify, and support forward-looking proposals that might otherwise "fall between the cracks". In many cases, this support generates unexpected early discoveries and allows researchers to turn their attention toward significant new opportunities to serve the Nation. When that happens, NSF can further realign its research portfolio to help American science seize these moments.

For example, support of early discoveries and subsequent realignments were key to the development of CRISPR, a transformative biotechnology that revolutionizes our ability to edit the genetic code of any living organism. The discovery of CRISPR emerged from a combination of NSF research funding programs over many years and exemplifies the elongated time scale on which benefits from fundamental research can occur. CRISPR is now accelerating discovery across many fields of biology, medicine, and even material science. One exciting application is correcting human genetic diseases such as sickle cell anemia, and it is worth noting that the 2020 Nobel Prize in Chemistry was awarded to CRISPR's NSF-supported discoverers.

From its beginning, NSF has pioneered a world-leading approach for supporting research, an approach that other countries have admired and attempted to emulate. By applying its Merit Review,[2] NSF leverages expertise from all over the country to respond effectively to each successive wave of new ideas. For funding decisions made in FY 2020, the most recent year for which complete data is publicly available, over 30,000 individuals reviewed proposals, served on panels, or both. Working together, these groups and individuals help NSF support the cutting-edge of innovation in science.

Supporting the Nation's Full Range of Talent
In FY 2023, NSF expects to support almost 140,000 students and researchers via awards to nearly 2,000 organizations and institutions, in all states and territories. For many STEM topic areas, NSF represents the area's largest federal funder of academic research, including artificial intelligence, environmental sciences, mathematics, social and behavioral sciences, biology, and computer and information science. NSF's deep and vigorous relationships with the Nation's researchers and research institutions give it profound convening power to identify scientific challenges, advance on technical opportunities, and solve societal problems.

For example, NSF's support of early-stage economics research on poverty over five decades has transformed how governments and other organizations around the world tackle the problem. These researchers, many of whom have won Nobel Prizes, have helped to lift millions of people out of poverty.[3]

Operating with Urgency and Strategy
To accomplish its science, technology, economic, and societal goals requires that America excel at both the "short game" and the "long game." The "short game" is the ability to transform the knowledge that we have into products, practices, and instruments that we can use to solve problems, create change, and empower people right now. The "long game" is making sure that the knowledge base from which our country will need to draw in the future is as strong as possible—with the imperative

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[2] www.nsf.gov/bfa/dias/policy/merit_review/
[3] www.nsf.gov/news/special_reports/nobelprizes/eco.jsp

that continuing American leadership will require this knowledge base to remain at the forefront of scientific advancement. NSF's research portfolio offers benefits at a range of timescales. This approach has fueled generations of innovators and innovations and created societal opportunities. NSF's strategic focus not just on supporting the best science today, but also on planting seeds for future generations of research, has helped America build back better generation after generation.

For example, outcomes from NSF's early-stage investments in core areas of science and research—that is, outcomes from prior research portfolio investments—are seen in many places, including the polymerase chain reaction (PCR) testing technique that has been critical in the fight against COVID-19 and the synthetic biology findings that yielded vital components of the COVID-19 vaccines. Connectivity has also been of crucial importance during the pandemic, and over recent decades NSF-funded researchers have developed technologies that help the internet traffic stay scalable globally and have discovered innovative approaches that improve connectivity in rural areas, including Navajo Nation lands.

Another example can be seen in an interdisciplinary program, Predictive Intelligence for Pandemic Prevention (PIPP), which was created in FY 2021 in response to the COVID-19 pandemic. This initiative focuses on fundamental research and capabilities needed to tackle grand challenges in infectious disease pandemics through prediction and prevention. Projects must identify an innovative interdisciplinary grand challenge that engages integrated computational, biological, engineering, and social/behavioral approaches to formulate and solve critical problems relating to predictive intelligence for pandemic prevention. PIPP activities place great emphasis on high-risk/high-payoff convergent research that has the potential for large societal impact, and funded teams are expected to work across scientific, disciplinary, geographic, and organizational divides, push conceptual boundaries, and build new theoretical framings of the understanding of pandemic predictive intelligence.

Budget Justification

Scientific research is NSF's most fundamental and universal activity. At the FY 2023 Request level, NSF's investments in such research—the Discovery Engine—represent an ongoing commitment to federally funded R&D and allow the Foundation to support a broad range of programs in all NSF directorates and offices. All NSF directorates participate, supporting over 400 disciplinary and interdisciplinary programs across the Foundation.

The requested research funding in FY 2023 will serve and empower American researchers to lead the world in vital scientific advances for decades to come. The increases requested in this budget will serve to reduce the number of high-quality curiosity driven research proposals that are not funded. If the requested funding is not provided, the discoveries and societal benefits this lost research offers will be delayed, deferred, or lost entirely. The increased funding for research in this budget will accelerate the pace of discovery, tighten the cycle from idea to funding to results, and support national competitiveness in the most important areas of science and engineering. Just as today's artificial intelligence revolution has its roots in NSF research portfolio investments going back over many

decades,[4] the opportunity for future revolutions rests with this additional investment in the portfolio going forward.

At the FY 2023 Request level, through the Discovery Engine rubric, NSF will:

- Evaluate almost 50,000 proposals through the competitive merit review process and make over 13,400 new competitive awards, of which almost 11,500 are expected to be new research grants.

- Fund over 77,000 researchers and postdoctoral associates plus over 50,000 graduate students and almost 49,000 undergraduate students.

- Expand support for **fellowship programs**. Touching all NSF directorates, this funding will invest in programs across the agency such as CISE Graduate Fellowships, ENG Postdoctoral Fellowships, SBE Postdoctoral Research Fellowships, and STEM Education Postdoctoral Research Fellowships. In addition to the Discovery Engine theme, this funding includes, but is not limited to, support for the goals described in the Equity theme.

- Provide leadership through NSF's **National Center for Science and Engineering Statistics** (NCSES) in government-wide evidence building activities and initiatives, including standing up the first-ever standard application process for applying to access restricted-use data from statistical agencies and units, as well as implementing the proposed National Secure Data Service through the expansion of America's DataHub.

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[4] National Academies. Information Technology Innovation: Resurgence, Confluence, and Continuing Impact. www.nap.edu/read/25961/chapter/1