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Introduction

Chairman Cartwright, Ranking Member Aderholt, and Members of the Subcommittee, it is a privilege to appear before you today to discuss how the National Science Foundation is building on decades of successful investments and breakthroughs in science, engineering, and technology to ensure that the United States remains the global leader in innovation into the future.

Established by the National Science Foundation Act of 1950 (P.L. 81-507), NSF is an independent federal agency charged with the 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 is unique in carrying out its mission by supporting research across all fields of science, technology, engineering, and mathematics, and at all levels of STEM education. NSF investments contribute significantly to the economic and national security interests of the nation, and development of a future-focused science and engineering workforce that draws on the talents of all Americans resulting in the creation of new businesses, new jobs, and more exports.

Over the past 72 years, NSF has funded research and researchers, innovations and innovators, and world-class infrastructure that has garnered incredible benefits to the nation. The Internet, 3D printing, and CRISPR technologies that enable everything from the development of COVID-19 vaccines to climate- and disease-resistant crops are all examples of the outcomes and benefits of NSF investments. Many of the technologies and industries that are the drivers of national competitiveness today—artificial intelligence, quantum information science, advanced manufacturing, and advanced wireless and biotechnology, to name a few—are rooted in NSF support, over the course of multiple decades in many cases, for research at the frontiers of science and engineering.

Securing the Future

Since the end of World War II, the United States has been the global leader in science, engineering, and technology due to the vision of leaders like Vannevar Bush and sustained investment by the federal government. The decision to make long-term investments in basic research was not just a decision to make science and engineering a priority alongside the economy, national defense, and national health—what we have learned is that these investments are an engine that strengthens each of these national priorities.

Today, we are facing challenges to that leadership as other nations seek to replicate our success, especially to control the future of technologies. According to the 2022 Science and Engineering Indicators report, “The State of U.S. Science and Engineering,” published by the National Science Board and prepared by NSF’s National Center for Science and Engineering Statistics, while the United States remains the world leader in global research and development, the rate of growth of research and development and science and technology capabilities by other countries, including China, has outpaced that of the United States in recent years. The 2022 report also shows that while industry performs the substantial majority of U.S. R&D, the federal government continues to be the largest investor in basic research. However, the proportion of U.S. R&D funded by the federal government, across all research types, has declined since 2010.¹

As we look to the future, it is critical that we foster the nation’s capacity to produce breakthroughs, to innovate, and to cultivate the diverse domestic talent necessary to power our country forward. Our economic and national security depend on our ability to invest heavily in the technologies of today while making the discoveries that are the foundation for the technologies of tomorrow; to seed innovation everywhere by building ecosystems of innovation in every region of the country; and to develop our domestic talent across every geographic and demographic background. The President’s FY 2023 Budget Request of \$10.5 billion for NSF makes historic investments in each of these areas.

Strengthening Established NSF

By seeding strategic investments, NSF explores the frontiers of discovery and innovation, and makes possible breakthroughs and advances that place the United States at the forefront of global leadership in science and technology. With the continued support of Congress, NSF has been able to sustain support for high-risk, high-reward research that produces incredible benefit for the American people. For example, more than four decades of NSF investment preceded the detection of gravitational waves from merging black holes billions of light years from Earth. This discovery was groundbreaking, with the lead researchers winning a Nobel Prize in Physics in 2017. To achieve this feat, they had to develop and refine new equipment and technologies to achieve their goals—and the development of these ultra-sensitive sensors and precision detection techniques they are pursuing today could very well prove to have incredible impacts on our everyday lives in the form of transformative future technologies, like quantum sensor technology.

Curiosity-driven research has proven to be an engine of economic growth. Since its inception, NSF has been a foundation for the industries of the future. Each year, thousands of researchers expand

¹ [\[1\] National Science Board, National Science Foundation. 2022. *Science and Engineering Indicators 2022: The State of U.S. Science and Engineering*. NSB-2022-1. Alexandria, VA. Available at <https://nces.nsf.gov/pubs/nsb20221>](https://nces.nsf.gov/pubs/nsb20221)

the base of human knowledge and, in doing so, unlock new possibilities. They have built autonomous vehicles; revolutionized our wireless networks; developed life-saving medical technologies; transformed manufacturing; and brought digital tools to agriculture, transportation, and education. Curiosity-driven, exploratory research is a critical component to the nation's current and future success. This will continue to be our central focus: to accelerate discovery and to enhance state-of-the-art research capabilities.

To that end, the President's FY 2023 Budget Request includes \$9.8 billion, an increase of \$1.6 billion above the FY 2022 enacted level, to support research across the spectrum of science, engineering, and technology, including biological sciences; computer and information sciences; engineering; geosciences; math and physical sciences; social, behavioral, and economic sciences; and STEM education. With this additional funding, NSF will continue to be the champion of the fundamental research that is strengthening our science and engineering enterprise at speed and scale.

Within the request are key priority areas where NSF plays a leading role in addressing issues of national importance. For example, the request includes funding to accelerate climate research, increasing our understanding of the impacts of climate change and developing corresponding solutions. NSF has been investing in fundamental research at the heart of global climate issues for several decades. Long-term, continuous, and consistent observational records are a cornerstone of global climate science and resilience research. NSF supports a variety of research observation networks that complement, and are dependent on, the climate monitoring systems maintained by our federal partners. The results of NSF investments have helped us understand climatic phenomena, and helped communities design mitigation strategies, strengthen adaptation capabilities, and build more resilient futures.

Focal areas of the FY 2023 Request include Clean Energy Technology (CET) and the U.S. Global Change Research Program (USGCRP). The FY 2023 request invests \$500 million in CET spanning high-risk, high-reward ideas from researchers across the science and engineering spectrum. These investments are needed to create broad new understanding and innovations that may increase energy efficiency, enhance sustainability, mitigate climate change, or lead to other societal benefits. NSF's portfolio spans longstanding programs as well as focused new opportunities and will continue to advance the fundamental science and engineering underlying clean energy technologies and infrastructure that decrease energy prices and build our domestic supply chain. NSF also will support multidisciplinary research in areas such as affordable green housing and sustainable systems for clean water, clean transit, and other infrastructure.

In FY 2023, \$913.4 million is requested for NSF to continue to support research that contributes to the USGCRP goal to accelerate action on two fronts: (1) advance scientific knowledge of the integrated natural and human components of the Earth system, focusing on changes that pose the biggest risks and opportunities to society, and (2) provide the scientific basis to inform and enable timely decisions on adaptation and mitigation. NSF will continue to engage with other USGCRP agencies on priorities from intra-seasonal to centennial predictability, predictions, and projections; water cycle research; impacts of climate change on the nation's critical ecosystems, including coastal, freshwater, agricultural and forests systems; understanding the impacts of global change on the Arctic region and effects on global climate; and fundamental research on actionable science. In addition, NSF will seek greater integration of social-science research, methodologies, and

insights into understanding and supporting responses to global change, improving computing capacity, and maintaining needed observational capabilities over time.

For example, in FY 2023, NSF will develop the National Discovery Cloud (NDC) for Climate, a new resource that will federate advanced computing, data, software and networking resources, democratizing access to a cyberinfrastructure ecosystem that is increasingly necessary to further climate-related science and engineering.

Investing in Innovation and Emerging Industries

Equally important to our nation's competitiveness and success is use-inspired, solutions-oriented research, which has been a critical part of NSF's mission throughout its history. Intense global competition and a rapidly changing technological landscape requires the United States to take a different approach to research and development investment that brings science and technology innovations to market much more rapidly. Doing so requires unleashing the untapped economies of innovation across the nation and more tightly integrating curiosity-driven research and use-inspired outcomes. NSF fosters an environment ripe for innovation focused on economic and societal progress. Many of today's foremost national and societal challenges such as health care and education demand deeply multidisciplinary, multi-sector, solution-oriented research to achieve much-needed science and technology innovations. We must enable collaborations spanning diverse institutions, sectors, and geographies to co-create new technologies and solutions to address these challenges and accelerate prosperity.

With the support of the Administration and Congress, NSF has launched its first new directorate in more than thirty years. The new Directorate for Technology, Innovation and Partnerships (TIP) sits at the crossroads of exploratory, curiosity-driven research, use-inspired, solutions-oriented research, and translational research across all disciplines and investment models. Significant resources are needed to ensure that TIP will have the transformative impacts it is designed to achieve. That is why, in FY 2023, \$880 million is requested for TIP to work with programs across NSF and with other federal and non-federal entities to expedite technology development in emerging industries. This investment is crucial to addressing societal and economic challenges, while maintaining the United States' technological leadership. TIP will leverage decades of NSF investments in areas like artificial intelligence and quantum information science coupled with accelerating the translation of research results from the lab to the market and society. TIP will also cultivate new education pathways, leading to a diverse and skilled technical future workforce comprising researchers, practitioners, technicians, and entrepreneurs.

Partnerships within the agency, with other agencies, industry, non-profit organizations, and like-minded international partners are also crucial to our success. TIP will leverage NSF's unique relationships with the academic community and grow the agency's collaboration with industry to spur innovation throughout the nation. The NSF Regional Innovation Engines (NSF Engines) will engage local communities, academia, government partners, industry, philanthropy, and others to identify issues of local, regional, and national importance, and to drive innovation in critical and emerging technologies to address these issues. The NSF Engines will be geographically distributed to ensure that we are unlocking the innovation that we know exists everywhere.

The FY 2023 Budget Request proposes increased funding in six emerging industries where continued investment in both exploratory, curiosity-driven research and use-inspired, solutions-

oriented research is needed to sustain U.S. leadership, support economic development, and secure our national security.

(1) Advanced manufacturing is essential to almost every sector of the U.S. economy, spurring it forward by increasing productivity, enabling new products, and opening new industries. The FY 2023 Request includes \$421 million for research to develop innovative technologies to create products and processes with higher performance, higher efficiency, and greater capabilities. NSF programs accelerate advances in manufacturing materials, technologies, and systems; workforce development; and translational activities that speed advances from the lab to the market.

(2) Advanced wireless networks and systems provide the communications backbone that connects users, devices, applications, and services that will continue to enrich America's economy. NSF has a proven track record of investing in fundamental research that advances wireless technologies. For example, today's fifth-generation ("5G") wireless networks and systems were enabled by two decades of ground-breaking NSF-funded research on millimeter-wave capabilities, advanced antenna systems, and novel algorithms and information processing protocols. NSF partners with other federal agencies and industry on such research. Looking forward to FY 2023 and beyond, NSF-supported research will make possible innovations in areas critical to future generations of wireless networks and systems, such as new wireless devices, circuits, protocols, and systems; security and resilience; mobile edge computing; distributed machine learning, and inferences across mobile devices; and fine-grained, real-time dynamic spectrum allocation and sharing. In FY 2023, \$168 million is requested for this research, which will generate new insights capable of making wireless communication faster, smarter, more affordable, and more robust and secure—with profound implications for science and society.

(3) Artificial intelligence (AI) is advancing rapidly and holds the potential to vastly transform our lives. NSF is the largest non-defense funder of artificial intelligence research and the agency's ability to bring together numerous fields of scientific inquiry uniquely positions the agency to lead the Nation in expanding the frontiers of AI. Additionally, through collaboration and coordination with the Office of Science and Technology Policy, NSF leadership is helping to drive and coordinate AI R&D efforts across the government. In addition to foundational research advancing the frontiers of learning, reasoning, and planning, the key to harnessing the promise of artificial intelligence is the use-inspired and translational research that links artificial intelligence and economic sectors such as agriculture, manufacturing, transportation, and personalized medicine. Equally important is the investment in education and learning, including growing the human capital and institutional capacity needed to nurture the next generation of artificial intelligence researchers and practitioners. In FY 2023, \$734 million is requested for NSF's AI investments, including continued support for the National AI Research Institutes program, a growing partnership with other federal agencies and the private sector, to create national hubs for universities, federal and local agencies, industry, and nonprofits to advance AI research and workforce development.

(4) Biotechnology comprises the data, tools, research infrastructure, workforce capacity, and innovation that enable the discovery, use, and alteration of living organisms, their constituent components, and their biologically-related processes. NSF has long supported the breadth of fundamental research that catalyzes ongoing developments in biotechnology. In FY 2023, \$392 million is requested for NSF investments that will include continued support for discovery of fundamental biological principles and the development of biotechnologies, advances in

bioinformatics, computational biology, and systems biology, as well as advances in the future biotech workforce.

(5) Microelectronics and semiconductors are omnipresent in today's world—in transportation, communications, healthcare, manufacturing, information technology, and nearly every other part of our daily lives. Yet, U.S.-led innovations in this area have slowed in recent decades, and the Nation is now facing historically unprecedented global competition and chip shortages impacting numerous sectors of the economy. The overarching objective of NSF's investment in microelectronics and semiconductors is to develop new paradigms in semiconductor capabilities. With the FY 2023 request of \$146 million, NSF will continue to invest in foundational research, in use-inspired research, and in partnerships and infrastructure, including access to chip fabrication facilities for the research community, to seed a vibrant future for microelectronics and semiconductors in the United States.

(6) Quantum Information Science (QIS) research will form the basis of one of the major technological revolutions of the 21st century. NSF investments advance fundamental understanding of uniquely quantum phenomena that can be harnessed to promote information processing, transmission, and measurement in new ways. Building upon more than three decades of exploratory discovery, NSF investment in QIS will help propel the Nation forward as a leading developer of quantum technology. In FY 2023, \$261 million is requested for NSF to invest in foundational quantum science advances, helping mature a relatively new field, which will have implications for computing, communications, and many other critical industries.

Investing in a Diverse and Inclusive STEM Workforce

There is tremendous untapped STEM potential throughout the nation. To meet the needs of the future workforce that is necessary for successfully seeding innovation throughout the nation, every person needs access to quality STEM education opportunities. Every demographic and socioeconomic group in every geographic region of the country is full of talent that must be inspired and motivated to participate in STEM and contribute to the nation's innovation enterprise. We must scale existing pathways into STEM fields and create new tracks into science and engineering. The FY 2023 request includes \$1.38 billion for STEM education in support of the scientists and engineers of today and tomorrow.

Each year, NSF investments reach approximately 300,000 people at almost 2,000 institutions in every state and territory. Through their work on NSF-supported grants, students, researchers, faculty, technicians, entrepreneurs, and others develop the skills and knowledge that prepares them for the jobs of the future. To ensure continued global leadership in science and technology, we must inspire, nurture, and advance domestic talent across our nation. The future depends on investment in inclusion, in diversity, in training STEM educators, and in inspiring the next generations through formal and informal learning. Continued global leadership also requires investment in the next generation of scientists trained to pursue questions beyond the traditional scientific disciplines. NSF is investing in education research across all levels of learning—from preK-12 through graduate education and beyond—which then informs education and training programs to better develop skill sets in cutting-edge technologies, promote highly collaborative team science, and foster greater diversity in the workforce.

NSF is strongly committed to the development of a future-focused science and engineering workforce that draws on the talents of all Americans. Increasing equity in underserved

communities must span a wide range of stakeholders, from individuals traditionally identified as underrepresented or underserved, to institutions of higher education that serve groups underrepresented in STEM, to those communities, lands and jurisdictions across the country that currently lack resources and opportunities for robust education, workforce development, and regional innovation.

In FY 2023, NSF intends to build on existing programs and develop new ones to strengthen and scale equity investments. NSF will focus on those groups underserved and underrepresented in STEM and will be more intentional in how we engage Minority Serving Institutions (MSIs). NSF will further expand support for individuals and institutions in EPSCoR jurisdictions to ensure geographic diversity.

In FY 2023, NSF requests \$50 million to launch a new initiative called Growing Research Access for Nationally Transformative Equity and Diversity (GRANTED). GRANTED will improve the nation's research capacity at emerging and underserved research institutions through a variety of mechanisms and programs aimed at advancing the geography of innovation and engaging the Missing Millions, the millions of young people and students who have the talent and drive to be part of the STEM community but who have not been able to access STEM opportunities. It will support the enhancement of research administration and post-award management as well as the implementation of effective practices for competitive proposal development, through mechanisms such as research-coordination networks (RCNs) and institutional partnership grants, ideas labs, and research enterprise hubs in different geographic regions. GRANTED funding in FY 2023 will focus on support for MSIs and aim to mitigate the barriers to competitiveness at underserved institutions within the nation's research enterprise as NSF contributes to the Administration's priority on equity.

World-Class Research Infrastructure

NSF invests in world-class research facilities, instrumentation, and scientific capabilities to ensure that researchers have access to the most cutting-edge scientific equipment. Through the Major Research Equipment and Facilities Construction (MREFC) projects, NSF has built the world's most powerful solar telescope, transformative optical and radio telescopes, state-of-the-art research vessels, and complex facilities in the harshest environments, including at the South Pole.

The FY 2023 request continues these investments, including long-term upgrades of NSF's major Antarctic infrastructure. It also supports construction of the Vera C. Rubin Observatory, two detector upgrades at the High Luminosity-Large Hadron Collider, and the Regional Class Research Vessels. NSF is also investing in smaller scale, but equally important research infrastructure that serves a vital purpose for the United States' research and innovation enterprise. The Mid-scale Research Infrastructure program is aimed at transforming scientific and engineering research fields as well as inspiring STEM talent. Mid-Scale Research Infrastructure (RI) can also serve as a proving ground for new and innovative major research facilities. In FY 2023, NSF will invest a total of \$126.25 million in Mid-scale RI, split between two tracks, Mid-scale RI-1 (\$50.0 million), funded through the Research & Related Activities account, and Mid-scale RI-2 (\$76.25 million), funded through the MREFC account. Through these two tracks, the Mid-scale RI program is providing U.S. researchers access to critical infrastructure, including testbeds, living laboratories, and prototyping facilities, across the spectrum of disciplines supported by NSF.

The Nation's science and engineering activities rely on facilities and instruments that are geographically and technically accessible, cost-effective, and managed well. To meet the infrastructure needs of the entire community, NSF is dedicated to supporting activities that ensure that instrumentation and research infrastructure can be designed, developed, acquired, or constructed across the Nation, through programs with focused oversight and targeted investments. Moreover, a sizeable portion of NSF's resources is invested in the ongoing operations and maintenance (O&M) activities necessary to keep research infrastructure at the cutting edge, and fully operational and accessible to those who use it to advance the boundaries of science.

The FY 2023 facilities O&M request continues to reflect a balance among multiple priorities. NSF divisions carefully allocate resources between research grants and O&M costs for research infrastructure. In addition to the regular O&M funding that keeps facilities functional, support for upgrades, significant periodic maintenance, and infrastructure renewal must also be addressed within Facilities O&M, which accounts for 10 percent of NSF's total request in FY 2023. NSF continues to explore ways to invest in research infrastructure at all scales in order to keep pace with changing technologies, increased demand by users, and expanding research opportunities.

NSF Responsiveness to COVID-19

NSF is grateful to the Administration and Congress for the support of the research ecosystem during the COVID-19 pandemic. With the funding provided by the "Coronavirus Aid, Relief, and Economic Security Act," or "CARES Act," NSF was able to mobilize the research community to make critical contributions to fighting the SARS-CoV-2 virus, including research to model the virus's structure, create new products to mitigate the virus's spread, and develop new treatments and vaccines. From equipment delays and reagent shortages to lost training time and missed field research, the pandemic also strained research projects in unique ways. With the continued support from Congress and the Administration, including the \$600 million provided in the American Rescue Plan Act of 2021 (ARP), NSF has been able to support groups of individuals and institutions most affected by the pandemic, as well as those at vulnerable transition points in their research careers. With more than \$450 million of the ARP funding obligated to date, NSF has been able to make more than 1,300 awards spanning all disciplines of science and engineering—supporting researchers, students, facilities and more. Thanks to these investments, NSF has been able to support innovative research ideas and sustain critical research talent that is central to our long-term competitiveness that could have been lost during the pandemic without the support that the Administration and Congress made available.

Securing Taxpayer-Funded Research

NSF is expanding capabilities and competencies to protect the U.S. science and engineering enterprise through its Research Security Strategy and Policy activity. In January 2022, the Office of Science and Technology Policy, through the National Science and Technology Council, issued implementation guidance for National Security Presidential Memorandum 33 (NSPM-33) on the National Security Strategy for United States Government-Supported Research and Development. NSF is working together with other federal research agencies to establish uniform mechanisms for researchers to provide agencies with consistent information on their appointments, activities, and sources of research support; many of these mechanisms will be made available to the community during FY 2023. Consistent with its published System of Records Notice, NSF has established processes to proactively identify conflicts of commitment, vulnerabilities of pre-publication research, and risks at various stages of the research funding enterprise from proposal submission

to the performance of NSF-funded research. To ensure clear understanding of research security issues, NSF disclosure requirements, and the tenets of beneficial international collaboration, NSF is leading the efforts to develop training resources for staff and the research community that will continue to be refined in FY 2023. NSF is also commissioning a JASON study in FY 2022 to provide guidance on the establishment of a Research on Research Security funding program that is expected to begin in FY 2023.

NSF participation in discussions with the U.S. research community and with international colleagues is key to the success of the agency's activities, which includes the development of common frameworks for understanding research security. That is why NSF is co-leading the U.S. efforts to work with G7 nations on research security and integrity. NSF is committed to strong partnerships across the federal government, with academia, and with our like-minded international partners to ensure that we can uphold the values of openness, transparency and reciprocity that have made the international research environment so successful.

Conclusion

At a time of intense global competition, the FY 2023 Budget Request for NSF positions the agency to lead the nation in innovation, discovery, and STEM education to build a more diverse and inclusive workforce and unleash economic and societal progress. With the new TIP Directorate established, NSF is well positioned to leverage the uniquely American innovation system in which investment in fundamental research is intertwined with strong partnerships among government, academia, and industry. With a keen focus on strengthening NSF's investments in exploratory, curiosity-driven research and use-inspired innovations, NSF will build on seven decades of preeminence in STEM to catalyze partnerships that produce breakthroughs and advancements in emerging industries like artificial intelligence and quantum information science. In this way, NSF will ensure that the United States is in the vanguard of global competitiveness.

Thank you for the opportunity to testify before you today. With the continued support of this Committee and the Congress, NSF will continue to unleash rapid innovations, and foster ecosystems of innovation throughout the country to ensure that the United States remains the global leader in science, engineering, innovation, and technology.