ADVANCE EMERGING INDUSTRIES FOR NATIONAL AND ECONOMIC SECURITY

Description and Rationale

For more than 70 years, NSF has supported fundamental and translational research across a broad range of science and engineering fields, enhancing U.S. national security, U.S. manufacturing and industrial productivity, and U.S. workforce development including addressing inequitable access to education and opportunity. NSF investment in high-risk, high-reward research has expanded human knowledge and unlocked entirely new technologies and industries. This has given rise to autonomous vehicles, revolutionary next-generation wireless networks and systems, novel computational platforms, life-saving medical devices, advanced manufacturing, and precision agriculture. NSF investment has also bolstered national and economic security both by catalyzing and sustaining leadership in key technology focus areas, and by leveraging these technological advances in support of national security needs. For example, many NSF-funded breakthroughs have been taken up by other agencies as part of their missions.

As the U.S. faces intensifying global competition for science and technology leadership, NSF is ready to strengthen and scale investments that advance key technologies. NSF's investment in Emerging Industries, one of its foundational pillars, includes advances in several of the key technology focus areas authorized in the CHIPS and Science Act of 2022, including by (i) democratizing access to the infrastructure that researchers and students need to conduct in-the-wild experimentation of new concepts and capabilities; and (ii) harnessing the innovative spirit that exists in all corners of our country, which in turn allows anyone anywhere to pursue the jobs of the future and ensures sustained U.S. leadership for generations to come.

Additionally, NSF will invest in multiple key technologies, as advances across the spectrum of these areas and the underlying science and engineering disciplines are needed to harness the potential of these promising fields. Just as the convergence of the NSF-funded page-rank algorithm, wireless devices, touchscreen interfaces, and other innovations catalyzed unanticipated industries and U.S. dominance in mobility and e-commerce, there is similar opportunity for advances at the intersection of advanced wireless, advanced manufacturing, artificial intelligence, biotechnology, quantum information science, clean energy, and research infrastructure to lead to revolutionary new industries.

In FY 2025, NSF will advance the Emerging Industries by strengthening and scaling a dynamic, diverse, and well-coordinated portfolio of investments. As outlined below, NSF investments in FY 2025 will afford scaling of existing activities to accelerate outcomes and deepen impacts, while also launching new programs that will empower researchers and innovators to collaborate. Support for key technology focus areas that will drive Emerging Industries will come from across NSF.

Goal of Investment

NSF's portfolio in Emerging Industries aligns with its broader goals to energize the Nation's economic competitiveness, sustain our global leadership and resilience, expand the geography of innovation, and improve the quality of life for everyone. Specifically, NSF will (i) advance science and engineering research and innovation leading to key technologies as well as solutions to national, societal, and geostrategic challenges; (ii) accelerate the translation of fundamental discoveries from the lab to the

market and society, growing jobs and the U.S. economy; and (iii) create equitable education pathways to ensure every American can pursue high-wage, good-quality jobs.

Building on NSF's longstanding leadership in science and engineering research and education, a key focus will be to help Americans in all regions of the country develop and build new science- and engineering-driven innovation ecosystems that strengthen their communities and address vital local and national needs. NSF will strengthen and scale the full spectrum of fundamental research, from foundational, discovery-oriented research to use-inspired, solution-oriented research in Emerging Industries. This includes advanced manufacturing, advanced wireless, artificial intelligence, biotechnology, microelectronics and semiconductors, and quantum information science. A priority for this portfolio will be the development of partnerships that link academia, industry, government, philanthropy, investors, and civil society.

Potential for Impact, Urgency, and Readiness

The Nation faces a defining moment. Global competition for leadership and talent in science, engineering, and technology is at an all-time high. For the United States to remain a global leader, we must recommit to investing in research and innovation in key technologies, fostering dynamic new partnerships, and nurturing talent throughout the country, thereby encouraging the innovative spirit that has been the source of our leadership over the past seven decades. Investing now in research, innovation, and education will ensure the Nation's continued leadership in vital industries for decades to come. The Internet, Google, Qualcomm, 3D printing, the discoveries and tools that support the burgeoning biotechnology sector, and economic theory underpinning spectrum auctioning and kidney exchanges all serve as examples of the outcomes and benefits of NSF investments. 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 NSF support for research and innovation at the frontiers of science and engineering.

In FY 2025, NSF will catalyze and support research and innovation in Emerging Industries through investments that address the following:

- **Advanced manufacturing** (including robotics and automation) investments will accelerate breakthroughs in manufacturing materials, technologies, and systems through fundamental and translational, multidisciplinary research that transforms manufacturing capabilities, methods, and practices. NSF investments will further advanced manufacturing through advanced energy and industrial efficiency technologies, resilient manufacturing strategies, novel methods in engineering biology, next-generation materials, and the power of data science, automation, robotics, and machine learning to intelligently design and develop future approaches that are secure, sustainable, and resilient to natural and anthropogenic disasters.
- **Advanced wireless** (including communications technology and immersive technology) investments will advance knowledge gaps and innovations in areas critical to future generations of communications technologies and networks, such as novel wireless devices, circuits, protocols, and systems; mobile edge computing; distributed machine learning and inference on mobile devices; human-machine-network interactions; ultra-low-latency connections; and dynamic spectrum allocation and sharing, all while ensuring security for all users. For example, this investment will serve to advance both new active spectrum applications and spectrum used for non-commercial purposes, such as advanced receiver design and interference mitigation techniques for radio astronomy and atmospheric science. NSF investments will provide the

backbone that connects users, devices, applications, and services that will continue to enrich America's national and economic security.

- **Artificial intelligence (AI)** (including machine learning, autonomy, and related advances) investments will bring together numerous fields of scientific inquiry—including computer and information science; cognitive science and psychology; economics and game theory; education research; engineering and control theory; ethics; linguistics; mathematics; and philosophy—to advance the frontiers of trustworthy AI, including advancing perception, learning, reasoning, recommendation, and action in the context of specific fields and economic sectors. NSF investments are needed to develop new foundational AI theory and implementation techniques, as well as novel AI methods that are inspired by use cases in specific application domains and contexts.
- **Biotechnology** (including genomics and synthetic biology) investments will support fundamental and translational research, infrastructure, and education to understand and harness biological processes for societal benefit. It will propel advances in genomics, bioinformatics and data analytics, structural and computational biology, biophysics, synthetic and engineering biology, tissue and metabolic engineering, medical technology, development of new types of biomaterials, bio-inspired data storage and microelectronics, and biomanufacturing, as well as accelerate the ability to harness biological systems to create goods and services that contribute to agriculture, health, security, manufacturing, and resilience to climate change, including natural and anthropogenic disaster prevention and mitigation. As part of the National Engineering Biology Research and Development Initiative codified in the CHIPS and Science Act, NSF investments in research at the intersection of the biological, physical, chemical, data, computational and information sciences and engineering, and social, behavioral and economic sciences will accelerate scientific understanding and technological innovation in engineering biology as well as assure public acceptance of the products of engineering biology.
- **Microelectronics and semiconductors** (including advanced computer hardware) investments will address the microelectronics and semiconductor challenges facing our Nation due to technological and global trends, such as the end of Moore's Law and offshoring of semiconductor fabrication and manufacturing. NSF will advance novel semiconductor design and manufacturing, enabling future advanced computing systems, including quantum computing and networking technologies. Investments will also advance next-generation materials and highly parallel chip designs that will improve the performance of AI algorithms as well as integrate advanced energy efficiencies for low-power and high-performance devices that will drive a mobile and wireless future, and smart sensors that will interface between biosystems and electronics. Additionally, the CHIPS and Science Act provides NSF with $200 million over five years for semiconductor workforce development activities.
- **Quantum information science** investments will pioneer the development of quantum computing, communication, sensing, and networking to advance information processing, transmission, and measurement in ways that classical approaches can only do much less efficiently, or not at all. This investment will develop proof-of-concept devices, tools, systems, and applications with a demonstrable quantum advantage over their classical counterparts. For example, investments in research on quantum sensors will enhance resolution and detection capabilities beyond the standard limits for classical technologies.

The parameters of NSF's investments in the Emerging Industries in FY 2025 are informed by findings from major reports, reviews, evaluations, and other evidence-building techniques. Some include:

Advanced Manufacturing

The *2022 National Strategy for Advanced Manufacturing*[1] provides a vision for U.S. leadership in advanced manufacturing. Manufacturing is essential to almost every sector of the U.S. economy, spurring growth by increasing productivity, enabling new products, and opening new industries. Rather than constrain the innovative solutions of tomorrow to the manufacturing methods we use today, we must push forward the frontiers of manufacturing to unleash and realize our national economic potential. NSF's investment in advanced manufacturing will continue to grow our nation's workforce, enhance supply chain resilience, and create products and processes with higher performance, fewer resources, and/or new capabilities.

Advanced Wireless

NSF co-chaired the formulation of a 2021 *National Strategy to Secure 5G Implementation Plan,*[2] which noted that fifth generation ("5G") wireless networks will drive our nation's prosperity and security in the 21st century. Of particular importance in the Implementation Plan was the need to invest in the security and resiliency of these networks. NSF's Resilient and Intelligent Next-Generation Systems (RINGS) program, in collaboration with two other federal agencies and nine companies, is directly aligned with this emphasis. In November 2023, NSF, together with NIST, published the *NextG Communications Research and Development Gaps Report*[3] to identify long-term technical gaps that, if addressed, could scale innovations across the wireless communications industry over the next 20 years and enable the development of new markets, products, and services, thereby contributing to economic growth.

Artificial Intelligence

The NSF Director sits on the White House AI Council, which coordinates the timely implementation of federal AI policies, including those set forth in the recent AI Executive Order (EO). NSF has successfully delivered on the initial taskings in the AI EO. For example, in January 2024, NSF, in collaboration with other federal agencies and the private sector, announced the launch of a National AI Research Resource (NAIRR) Pilot,[4] in keeping with the recommendations of a January 2023 report by the Congressionally mandated NAIRR Task Force, *Strengthening and Democratizing the U.S. Artificial Intelligence Innovation Ecosystem: An Implementation Plan for a NAIRR.*[5] NSF also co-led the *National AI R&D Strategic Plan: 2023 Update,*[6] which laid out nine strategies for advancing AI research, education, and research infrastructure.

Biotechnology

President Biden's Executive Order on *Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy*[7] laid out a whole-of-government approach to advance biotechnology and biomanufacturing towards innovative solutions to keep the U.S. healthy

[1] www.manufacturingusa.com/reports/national-strategy-advanced-manufacturing

[2] www.ntia.gov/files/ntia/publications/2021-1-12_115445_national_strategy_to_secure_5g_implementation_plan_and_annexes_a_f_final.pdf

[3] www.nist.gov/publications/nextg-communications-research-and-development-gaps-report

[4] https://new.nsf.gov/focus-areas/artificial-intelligence/nairr

[5] www.ai.gov/wp-content/uploads/2023/01/NAIRR-TF-Final-Report-2023.pdf

[6] www.whitehouse.gov/wp-content/uploads/2023/05/National-Artificial-Intelligence-Research-and-Development-Strategic-Plan-2023-Update.pdf

[7] www.whitehouse.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/

and secure. Among its directives, NSF was charged with identifying bold goals and cross-cutting research and development needs that, if fully funded, would provide the foundational discoveries, innovations, and infrastructure essential to advance all sectors of the bioeconomy. Additional reports associated with the Executive Order identify key needs in workforce development, data and associated infrastructure, and manufacturing innovation needed to advance the U.S. bioeconomy. The focus on biotechnology to advance the U.S. bioeconomy aligns with the theme area of emerging industries and the Administration's focus on economic recovery. Investments in this area will allow translating knowledge and tools into applications that promote the U.S. bioeconomy in public health, agriculture, energy, climate change, and security.

Microelectronics and Semiconductors

Microelectronics and semiconductors are omnipresent in transportation, communications, healthcare, manufacturing, information technology, and other industries. However, as noted in the CHIPS and Science Act, U.S.-led innovations in semiconductors and microelectronics have slowed, the Nation is facing unprecedented global competition, and the building blocks of today's microelectronics, which rely on scarce natural resources, are approaching fundamental limits in both size and energy efficiency. New paradigms of both capabilities and sustainability are needed for future microelectronics and semiconductors, as well as a strong domestic workforce. NSF investments aim to demonstrate sustainable new semiconductors and microelectronic devices capable of overcoming the looming natural limits of current technologies and architectures. These investments will also enable the training of a critically needed U.S. workforce capable of adapting and advancing these technologies for a broad range of societal needs.

Quantum Information Science

NSF's QIS Investments are influenced by the analyses and recommendations included in a series of NSTC reports. Among these are: the National Strategic Overview for QIS,[8] the *Quantum Frontiers Report*, *A Coordinated Approach to Quantum Networking Research*, *The Role of International Talent in Quantum Information Science*, the *QIST Workforce Development National Strategic Plan*, and *Bringing Quantum Sensors to Fruition.*[9]

Anticipated Potential Contributors

NSF's investments in FY 2025 will reflect an integrated portfolio allowing for rapid acceleration not just within each of the above areas but also at the intersections between them. Funding will further a broad suite of programs to advance research and innovation in key technology focus areas across all NSF directorates and offices through strategic partnerships with other federal agencies and the private sector. Increases will afford strengthening and scaling of NSF's substantial existing investment in Emerging Industries as well as initiating significant new initiatives.

[8] www.quantum.gov/wp-content/uploads/2020/10/2018_NSTC_National_Strategic_Overview_QIS.pdf

[9] All reports can be accessed via www.quantum.gov