QUANTUM INFORMATION SCIENCE (QIS)

Quantum Information Science Funding[1]
(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request
BIO	$3.28	-	$3.43
CISE	20.70	-	27.05
EDU	4.00	-	5.00
ENG	29.50	-	30.83
MPS	179.00	-	187.83
TIP	29.25	-	39.18
OISE	1.00	-	1.05
Total	**$266.73**	**-**	**$294.37**

[1] Funding displayed may have overlap with other topics and programs.

Overview

QIS research will advance fundamental understanding of uniquely quantum phenomena that can be harnessed for information processing, transmission, and measurement in ways that classical approaches do less efficiently, or not at all. Current and future applications of QIS differ from prior applications of quantum mechanics, such as lasers, transistors, and magnetic resonance imaging, by using distinct properties of quantum superposition and entanglement that do not have classical counterparts. The development of new applications for QIS will lay the groundwork for one of the major technological revolutions of the 21st century. Building upon more than three decades of exploration and discovery-oriented research, NSF investments in QIS will continue to propel the Nation forward as a leading developer of quantum technology. NSF investments are a key component of the National Quantum Initiative (NQI) and they align with the Administration's focus on critical and emerging industries.

NSF's QIS investments build upon the agency's long-standing and continuing foundational and translational activities in QIS as well as more recent opportunities for interdisciplinary teams, centers, and targeted workforce development efforts. 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,*[1] the *Quantum Frontiers Report,*[2] *A Coordinated Approach to Quantum Networking Research,*[3] *The Role of International Talent in Quantum Information Science,*[4] the *QIST Workforce Development National Strategic Plan,*[5] and *Bringing Quantum Sensors to Fruition.*[6] NSF Investments will

[1] www.quantum.gov/wp-content/uploads/2020/10/2018_NSTC_National_Strategic_Overview_QIS.pdf
[2] www.quantum.gov/wp-content/uploads/2020/10/QuantumFrontiers.pdf
[3] www.quantum.gov/wp-content/uploads/2021/01/A-Coordinated-Approach-to-Quantum-Networking.pdf
[4] www.quantum.gov/wp-content/uploads/2021/10/2021_NSTC_ESIX_INTL_TALENT_QIS.pdf
[5] www.quantum.gov/wp-content/uploads/2022/02/QIST-Natl-Workforce-Plan.pdf
[6] www.quantum.gov/wp-content/uploads/2022/03/BringingQuantumSensorstoFruition.pdf

continue to enable key work in all of the major areas of quantum computing, communications, sensing, networking, and simulation. Special attention as to how these areas connect with each other will accelerate development in all of them and lead to advances in quantum computers, quantum networks, and metrology. For example, quantum sensors that significantly enhance resolution and detection capabilities, and networks that can connect components of quantum systems without loss of fidelity. Collaboration with fields beyond the core of QIS will identify end users of new quantum technologies and help establish the market for new tools and applications, from security to biomedical. Ultimately, this work will allow quantum technology to become established on a sound footing and play a recognizable role in advancing the U.S. economy.

Consistent with and crucial to its mission, NSF will form partnerships with other federal agencies, industry, private foundations, national laboratories, and existing centers to leverage NSF's investments in QIS research and education. In addition, international cooperation with like-minded countries is critical to ensure that discoveries, and their resulting technologies, provide for economic growth and national security. NSF will continue to provide funding opportunities for QIS researchers to enable researchers' access to industry-built quantum-computing platforms and to support international collaboration efforts. In FY 2025, NSF will continue to support the Expand QISE program which focuses on enhancing the participation of academic institutions not currently participating in the national QISE initiative and promoting the inclusion of members of groups currently underrepresented in the field. NSF will support educational efforts in QIS across all levels ranging from higher educational to K-12 teachers and students.

Goals

- Answer key science and engineering questions to expand the fundamental understanding of quantum phenomena and systems and enable the translation of that basic knowledge into technological applications.
- Deliver proof-of-concept devices, applications, tools, and systems with demonstrable quantum advantages as compared to their classical counterparts, to lay the foundation for revolutionary 21st century quantum technologies.
- Empower the full spectrum of talent to which NSF has access to build needed capacity and generate the quantum-literate workforce that will implement the results of these breakthroughs, with a special focus on reaching out to MSI's and expanding the QIS workforce in ways that will enhance the diversity of that workforce through the inclusion of members of groups heretofore underrepresented in the endeavor.

FY 2025 Investments

In FY 2025, NSF will support the design and implementation phases of the National Quantum Virtual Laboratory (NQVL), which was initiated with a pilot phase in FY 2023. The NQVL is a community-wide infrastructure platform designed to facilitate the translation from basic science and engineering to the resultant technology, while at the same time emphasizing and advancing its scientific and technical value. The NQVL aims to develop and utilize use-inspired and application-oriented quantum technologies within the context of the academic environment. In the process, NQVL researchers will explore quantum frontiers, foster QISE workforce education and training, engage in outreach activities at all levels, and promote broadening participation, diversity, equity, and inclusion in QISE. Concurrently in FY 2025, NSF will continue its investment in the Quantum Leap Challenge Institutes

(QLCI), the Transformational Advances in Quantum Systems (TAQS) series of small-team awards, the Expand QISE efforts to enhance capacity in the QIS enterprise, and foundational core investments in individual investigator programs and disciplinary centers.

Investments by Program Component Area

QIS Funding by Program Component Area

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request
Foundational Quantum Info. Science Advances	$123.27	-	$147.92
Quantum Computing	41.96	-	55.93
Quantum Networks and Communications	32.42	-	30.34
Quantum Sensing and Metrology	28.82	-	36.16
Future Applications	31.30	-	18.76
Risk Mitigation	4.01	-	3.98
Supporting Technology	4.95	-	1.28
Total	**$266.73**	**-**	**$294.37**

Foundational Quantum Information Science Advances

Notwithstanding the significant progress that has been made in quantum technologies over the past several years, the field of quantum information science and engineering is still in its infancy. Many questions that lie at the heart of the field remain to be addressed and answered. At the same time, new discoveries enable new directions that open new as-yet-unexplored opportunities. NSF will maintain significant investment in the underlying disciplinary programs and will consider supporting new collaborative center-level activities in all areas that have the potential to enable these scientific breakthroughs.

Quantum Computing

Much progress has been made in superconducting circuits, ion-traps, and neutral atom quantum computing architectures. However, there is no single platform that has emerged as the definitive solution for quantum computing challenges. Furthermore, multiple architectures might simultaneously co-exist to support distinct types of quantum computations enabled by each. Therefore, NSF will continue exploring alternative quantum computing architectures that could emerge as viable options in the future. NSF will also continue to support research on the basic underpinnings and fundamental limits of quantum computing as defined by the underlying physical processes, architectures, and algorithms. At the same time, in collaboration with industry, NSF will continue to support researcher access to quantum systems and platforms to experiment in specific domains.

Quantum Networks and Communications

While the exact implementation of quantum processing nodes and qubits is still the topic of research and debate, the information between the quantum processing nodes in many cases will be carried by photons. Therefore, interfacing different types of qubits with photons is critical for the realization of scalable distributed quantum computational systems as well as for coherent connections between quantum platforms dedicated to computing, communication, and/or sensing. NSF will support cross-disciplinary teams of engineers, mathematicians, computer scientists, and physical scientists to develop basic research results that enable emerging quantum computing systems to interface with each other as well as with existing traditional computing systems.

Quantum Sensing and Metrology

Quantum sensors offer the most recognized near-term end-user applications of second-generation quantum technologies. Potential users cover the scientific spectrum, from precision measurements in physics to high-resolution imaging in biology to advanced seismology for earth sciences. Exploiting the potential offered by quantum-based sensors relies on establishing close connections between the builders and the users. NSF supports opportunities to achieve this through a variety of multidisciplinary programs and community-building activities such as the Research Coordination Networks and "Dear Colleague" letters emphasizing areas of mutual interest.

Future Applications

Use-inspired basic research and co-design with end-users continues to be a theme for several NSF investments in QIS. This applications-oriented research is supported by NSF programs such as NQVL, the NSF Lab-to-Market Platform (including the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs), the NSF Convergence Accelerator, NSF Industry-University Cooperative Research Centers, and NSF Regional Innovation Engines, all of which support meritorious QIS research and development activities. These opportunities are designed to promote the more rapid translation of basic quantum knowledge into the private sector. In FY 2025, investments in these programs will continue connections and collaborations with industry.

Risk Mitigation

Concomitant with investments that promote the development of new quantum-based computational and communications tools, NSF will support efforts to counter the risks that emerge with these new technologies, for example to understand cybersecurity in the context of quantum computing[7] to elucidate foundations of post quantum cryptography, and to consider security implications of quantum technologies.[8]

Supporting Technology

Building the QIS technology portfolio will require the simultaneous development of classical tools that are needed to perform research and develop prototypes. Working through existing disciplinary programs, NSF will support researchers who are developing tools and algorithms that are especially adapted to quantum applications.

[7] www.quantum.gov/wp-content/uploads/2022/11/2022-Workshop-Cybersecurity-Quantum-Computing.pdf
[8] www.whitehouse.gov/briefing-room/statements-releases/2022/05/04/national-security-memorandum-on-promoting-united-states-leadership-in-quantum-computing-while-mitigating-risks-to-vulnerable-cryptographic-systems/