QUANTUM INFORMATION SCIENCE (QIS)

Quantum Information Science Funding
(Dollars in Millions)

	FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request
BIO	$3.28	-	$3.28
CISE	20.70	-	24.28
EDU[1]	10.52	-	5.0
ENG	21.31	-	32.89
MPS	154.03	-	156.13
TIP[2]	20.53	-	38.42
OISE	0.09	-	1.00
IA	24.60	-	-
Total	**$255.06**	**-**	**$261.00**

[1] Formerly known as Directorate for Education and Human Resources (EHR).
[2] FY 2021 funding for TIP is shown for comparability across fiscal years.

Overview

QIS research will advance fundamental understanding of uniquely quantum phenomena that can be harnessed to promote information processing, transmission, and measurement in ways that classical approaches do less efficiently, or not at all. Current and future QIS applications differ from prior applications of quantum mechanics, such as lasers, transistors, and magnetic resonance imaging, by using distinct quantum phenomena—superposition and entanglement—that do not have classical counterparts. The development of these new applications will form the basis of one of the major technological revolutions of the 21st century. 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. These investments are a key component of the National Quantum Initiative (NQI) and address the Administration's focus on helping build emerging industries.

NSF's QIS investments build upon the agency's long-standing and continuing foundational investments in QIS as well as more recent, interdisciplinary investments in centers and small teams and targeted workforce development efforts. Investments will target all 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 communications networks, quantum sensors that enhance resolution and detection capabilities significantly, 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 2023 NSF will continue the Expand QISE thrust begun in FY 2022, which focused 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.

Goals

- Answer key science and engineering questions to facilitate the fundamental understanding of quantum phenomena and systems, as well as the translation of that fundamental knowledge into technological applications.
- Deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts that will form the basis of a revolutionary 21st-century technology.
- 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

Investments by Program Component Area

QIS Funding by Program Component Area
(Dollars in Millions)

	FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request
Foundational Quantum Information Science Advances	$71.64	-	$73.00
Quantum Computing	67.02	-	64.71
Quantum Networks and Communications	37.14	-	43.59
Quantum Sensing and Metrology	46.05	-	42.31
Future Applications	17.37	-	21.61
Risk Mitigation	9.54	-	11.08
Supporting Technology	6.30	-	4.70
Total	**$255.06**	**-**	**$261.00**

<u>Foundational Quantum Information Science Advances</u>
Notwithstanding the significant progress that has been made in QIS over the past five years, as a technology, the field 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.

<u>Quantum Computing</u>
Much progress has been made in superconducting and ion-trap quantum computing architectures, and NSF continues to lead the way through investments in approaches to scale these by at least a factor of ten or more. However, there is no single platform that has emerged as the leading contender, and multiple architectures might simultaneously co-exist to support distinct types of quantum

computations enabled by each. NSF will continue exploring alternative quantum computing architectures that could emerge as viable options in the future, as well as the basic underpinnings and limits of quantum computing as defined by the underlying physical processes and architectures. 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 will most likely 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 seismology in earth sciences. Exploiting the potential offered by quantum-based sensors relies on establishing close connections between the builders and the users. NSF would achieve this through a series of community-building activities such as Research Coordination Networks and “Dear Colleague” letters emphasizing areas of mutual interest.

Future Applications

In FY 2021, NSF initiated an investment in a QIS Convergence Accelerator track designed to promote the more rapid translation of basic quantum knowledge into the private sector. This investment will continue in FY 2022, together with on-going programs that support connections and collaborations with industry.

Risk Mitigation

Concomitant with investments that promote the development of new quantum-based computational and communications tool, NSF will support efforts to counter the risks that emerge with these new technologies.

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.