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Assessing U.S. Leadership in Quantum Science and Technology

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Chairman Babin, Ranking Member Lofgren, and Members of the Committee, my name is Dr. Saul Gonzalez, Deputy Directorate Head for the Directorate for Mathematical and Physical Sciences at the U.S. National Science Foundation (NSF). I am a particle physicist with years of experience in research in the U.S. and abroad. I started my federal career in 2003 at the U.S. Department of Energy where I spent a decade as a physicist in the Office of Science before coming to NSF as a program director in 2012. My federal career has also included a detail to the White House Office of Science and Technology Policy (OSTP), where I served as Assistant Director for Physical Sciences. Now as the Deputy Directorate Head for the Mathematical and Physical Sciences Directorate at NSF, I oversee research on astronomical sciences, chemistry and physics, and help lead the NSF-wide efforts in QIS.

It is an honor to be with you today to discuss the vital role NSF has played in the many recent exciting advancements in quantum information science (QIS) and how we continue to push the frontiers of QIS, bolstered by the 2018 National Quantum Initiative Act (NQIA) and in collaboration with partners across the federal research enterprise, including the Department of Energy (DOE), the National Institute of Standards and Technology (NIST), and the National Aeronautics and Space Administration (NASA).

Quantum information science was born out of the convergence of quantum mechanics, which governs how the universe works at a microscopic level, and information theory. Theoretical and experimental developments over the last decades have given us the possibility to encode, control, and manipulate information at these microscopic scales, using quantum superposition and entanglement, much like nature itself. This opens opportunities to use the building blocks of nature to process vast amounts of information in very small volumes. Quantum computers could, for example, simulate the nearly endless variety of molecular interactions to create new medicines that save lives. Quantum sensors can measure the previously unmeasurable, like the temperature inside a single human cell, allowing pinpoint detection and treatment of disease. Realizing this quantum advantage promises to improve human capabilities in the creation of new materials and medicines, the diagnosis and treatment of disease, and the simulation of complex physical and chemical phenomena, beyond the reach of classical computation. However, while we have come a long way since the discovery of quantum mechanics over a 100 years ago, much work remains to be done.

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." We meet this mission by supporting research across all fields of science, technology, engineering, and mathematics (STEM) and at all levels of STEM education, reaching 350,000 researchers, entrepreneurs, students, and teachers in an average year. NSF investments fuel groundbreaking discoveries, accelerate translation of research results to the market, and support the U.S. STEM talent of today and tomorrow.

This broad scope of STEM disciplines includes physics, materials science, mathematics, computer and information science, engineering, biology, and many others. NSF views this breadth as a great advantage. In fact, nearly all our programs related to QIS are, by necessity, multidisciplinary. This is beneficial in two ways: (1) we can leverage the unique expertise of each field towards delivering quantum solutions; and (2) the science and engineering domains have applications that can benefit from and drive the development of new quantum technologies. 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 cybersecurity to biotechnology.

The convergence of multiple science and engineering disciplines has accelerated the development of not only quantum technologies, but also artificial intelligence, biotechnology, and other science and technology priorities. Adding lab-to-market translation to this mix, breakthroughs in these fields have and will continue to spark entirely new industries, revolutionize the way we live and work, and promote America's competitiveness. Increasingly, NSF is also pursuing partnerships with the private sector, leveraging expertise and resources to identify new research directions and gain access to data and infrastructure.

The 2018 NQIA was a recognition of the urgency in maintaining and expanding U.S. global leadership in QIS and its applications and technologies. That urgency has only grown as the global race across a number of critical and emerging technologies, such as QIS, has accelerated, fueled in part by the ambitions of our global adversaries, such as the People's Republic of China (PRC). The U.S. has the ability, talent, and infrastructure to not simply maintain, but to grow our leadership across all critical and emerging technologies. At NSF, we consider this a core part of our mission and an economic and national security imperative.

A History of Sustained NSF Investment and Impact in QIS

For over 75 years at NSF, promoting the progress of science has been about pushing the frontier of knowledge about how the universe and everything in it works. This "discovery mindset" recognizes that the only way to push forward is to find out what lies just beyond that frontier. This approach succeeds spectacularly. Sometimes “success” is found in the new knowledge of which paths show promise and which are dead ends. By doing this early and often in the research lifecycle, we can accelerate, de-risk, and inform the later, and more resource-intensive R&D stages. These types of NSF investments over several decades have laid the framework for the “second quantum revolution” that is now taking place. From ultracold atoms for atomic clocks, to quantum optics for the Laser Interferometer Gravitational-Wave Observatory (LIGO), and superconducting circuits for quantum computers, early NSF investments have been critical for U.S. leadership in quantum technology.

The earliest investments in QIS at NSF were made through nearly 20 fundamental research programs in physics, materials science, computer science, mathematics, and engineering. While most did not carry the “QIS” label at the time, these programs had something in common: they harnessed fundamental quantum properties to explore new scientific frontiers and develop new technologies at the edge of traditional scientific disciplines.

These fundamental research programs delivered many advances that lay the foundation for what is QIS today and, equally important, they built a multidisciplinary community of researchers, who are now leaders training the next generation of the QIS workforce. Today, NSF investments support approximately 1,600 QIS projects at more than 260 institutions in 47 states led by over 2,000 investigators, and training over 2,500 graduate students.

Examples of early NSF-supported research that led to important advances in QIS range from awards to single investigators exploring an idea, “peeking over the frontier”, to large multi-disciplinary awards to multiple researchers carrying out “team science”.

Prominent quantum-focused companies such as IonQ and QuERA have roots in NSF-funded research: a 2001 NSF award on trapped ions for quantum computing led to the founding of IonQ, which is now a publicly traded quantum computing company currently valued at $17 billion. A 2002 NSF CAREER award on the Rydberg blockade concept and neutral atom simulators led to the creation of startup company QuERA.

An NSF award made in 2007 focused on quantum optics with superconducting circuits. This work accelerated the development of the transmon qubit, now used in IBM, Google, and Rigetti quantum computing systems. It also led to the founding of the startup company Quantum Circuits Inc., which was recently acquired by D-Wave for over $500 million.

In 2018, NSF funded the Software-Tailored Architectures for Quantum co-design (STAQ) multidisciplinary project led by Duke University to bridge the gap between quantum hardware and software. It was the first effort to address holistically the full quantum technology stack. The project led to performance improvements of early NISQ (Noisy Intermediate-Scale Quantum) systems and foundational advancements for future, more powerful quantum systems. Still active, the STAQ collaboration is on track to deliver a 96-qubit Quantum Computer by 2027. Two of the leading STAQ scientists are the co-founders of IonQ.

NSF has also funded three Physics Frontier Centers related to QIS: the Center for Ultracold Atoms at MIT and Harvard University (since 2000), JILA at the University of Colorado, Boulder (since 2006), and the Institute for Quantum Information and Matter at Caltech (since 2011).

NSF has funded quantum research by over 44 Nobel Prize winners. This includes NSF support for all three laureates of the 2025 Nobel prize in Physics. The underlying work for that prize on demonstrating quantum states and tunneling with macroscopic quantum systems was funded by NSF and other agencies starting in the 1980s. Now, a few decades later, we can see how that work was a pathfinder for the quantum computers being pursued by several startup and Fortune 500 companies today that are generating billions of dollars in U.S. private sector activity.

This history of investment ensured that NSF was well positioned to open the door for new possibilities under the banner of the 2018 NQIA.

Quantum Information Science at NSF since the 2018 NQIA

The NQIA recognized that to win the global race for a quantum technology future, that race had to be a whole-of-government effort. To ensure that would be the case, the NQI established the National Quantum Coordination Office at OSTP with an NSTC Subcommittee for QIS (SCQIS) to, among other things, develop a national strategy and coordinate agency activities in QIS. The SCQIS, co-chaired by NSF, brings together all the agencies with equities in QIS, including the four represented here today.

NSF investments in QIS under the NQIA can be organized around three goals, which are informed by the 2018 National Strategic Overview for Quantum Information Science and build upon the foundation of decades of NSF investments.

The first goal is to answer key science and engineering questions to expand the fundamental understanding of quantum phenomena and systems, and to overcome important science and engineering challenges.

The QIS fundamental research program has served to both pave the way for discovery and build the quantum workforce. As is the case with aspects of many emerging fields, given that it is too early to make certain technology choices, continued investment in fundamental QIS research offers the opportunity to de-risk current candidate technologies before scaling up or developing new ones altogether.

The NQIA also envisioned multidisciplinary centers for quantum research and education. These NSF Quantum Leap Challenge Institutes (QLCI) are large-scale multidisciplinary research projects motivated by major challenges for the development, application, commercialization, and pioneering use of quantum technologies. They catalyze breakthroughs on important problems, nurture a culture of discovery, provide workforce development opportunities, and create value-added from coordination. Each QLCI also leads education, training, and workforce development activities as may be needed for sustained leadership in QIS and related topics.

There are currently five NSF QLCIs, two of which are focused on quantum computing, one on quantum networks, and two on quantum sensing.

A recent highlight with potential impacts for health and medical applications is but one example of the positive impacts of these institutes. Scientists at the NSF Quantum Leap Challenge Institute for

Quantum Sensing for Biophysics and Bioengineering have turned a protein found in living cells into a functioning qubit, the foundation of quantum technologies. The protein qubit can be used as a quantum sensor capable of detecting minute changes and ultimately offering unprecedented insight into biological processes. The new quantum sensors could one day help doctors study neurological conditions like Alzheimer's disease, Parkinson's disease, stroke, and trauma. These biologically expressible qubits were in part enabled by the NSF investment in the QLCI.

In aggregate, the QLCIs collaborate with more than 140 academic institutions and 46 industry partners. They engage over 160 faculty, 170 postdoctoral researchers, and 630 undergraduate and graduate students, and have produced over 820 peer-reviewed research publications since their inception in 2020. A new competition is underway for the next phase of the QLCIs, which will enable NSF to build on the success of the program.

In addition to the QLCIs, examples of NSF’s center-scale QIS investments include the Engineering Research Center for Quantum Networking, focused on building the foundations of the quantum internet to reliably carry quantum data across the globe; the Center for Emergent Quantum Materials and Technologies, focused on the design, synthesis, growth, and use of materials and hybrid systems with large-scale quantum properties for applications in sensing, metrology, communication, and information processing; and two NSF Quantum Foundries, the NSF Quantum Materials Foundry and the Montana-Arkansas Quantum Foundry, that were established to accelerate quantum materials design, synthesis, characterization, and translation of fundamental materials engineering and information research for quantum devices, systems, and networks.

The second goal is to deliver proof-of-concept devices, applications, and tools with demonstrable quantum advantage as compared to their classical counterparts.

The National Quantum Virtual Laboratory (NQVL) program brings a co-design approach together with systems engineering to de-risk and mature emerging quantum technologies. The NQVL is a community-wide infrastructure platform designed to smooth the translation from basic science and engineering to the market. The NQVL is developing quantum infrastructure capability for testing, piloting, and prototyping in and across all four NQI areas – Quantum Computers, Quantum Networks, Quantum Sensing, and Quantum Simulations – with a particular focus on at-scale demonstration in relevant environments. Through the NQVL and related investments, NSF de-risks breakthrough technology to the point that it is suitable for adoption, commercialization, and scaling by the private sector. In other words, the NSF NQVL serves as an incubator of quantum technology.

In 2025, NSF awarded 11 NQVL Pilot projects to develop the conceptual design for use-inspired and application-oriented quantum technology testbeds. Four of those teams have recently advanced to the formal Design phase of the NQVL program. These Design teams include 67 researchers from 36 academic institutions, 6 Federally Funded Research and Development Centers, and more than 20 private sector partners.

Another recent example supporting this goal is the National Quantum Nanofab. This facility will enable quantum device fabrication, characterization, and packaging capabilities that are essential to advance QIS applications. It is an open-access facility for academic, government, and industrial users.

The third goal is to empower the full spectrum of talent to which NSF has access to build capacity and generate the quantum-literate workforce that will implement the results of these breakthroughs.

This goal is about expanding QIS research capacity, developing the workforce, and fostering QIS education to create a quantum-smart workforce. Most NSF support for workforce development in QIS takes place organically in the context of cutting-edge research. In aggregate, NSF currently supports over 2,000 faculty at over 300 universities and colleges in the U.S. to lead approximately 1,600 NSF-funded projects with over 4,000 graduate students, over 1,000 postdoctoral researchers, and over 2,000 undergraduate students performing basic and applied research in QIS.

Since the start of the NQI, NSF has roughly doubled the number of faculty and students who are working on NSF funded QIS projects. And still, supply is not keeping up with demand for talent in this area. At a recent NSF workshop, we heard the following point from a research team: "The US faces a critical shortage of people working in this area, which affects our national security, economy, and competitiveness on the global stage. This issue also intersects with related areas, such as the semiconductor industry."

Many existing programs at NSF also support the goals of the NQI. For example, the NSF Graduate Research Fellowship Program (GRFP) supports outstanding graduate students who are pursuing full-time research-based graduate degrees in STEM. Since the GRFP program started tracking QIS, NSF has provided 3-year fellowships for over 160 graduate students in this area. Students eligible for a GRFP Award are U.S. citizens or permanent residents.

Recognizing that to have a quantum-smart workforce, we needed to start with early education, NSF helped establish a national program focused on education in quantum science at the K-12 level. The program, called the National "Q-12" Education Partnership, was launched by OSTP and NSF in 2020. Q-12 is a consortium that expands access to K-12 quantum learning tools and inspires the next generation of quantum leaders. Q-12 is a partnership between National Security Agency's Laboratory for Physics Sciences and NSF. Support for this activity continued in FY 2025.

At a recent NSF Workshop on quantum education, a Principal Investigator involved in the Q-12 Education Partnership highlighted the importance of federal funding in quantum education. "For example, (1) The area is new, and thus there is limited capacity among experts. Most people are not familiar with QISE or teaching the concepts and thus federal funding can extend the reach of existing experts while also building local expertise in all 50 states. (2) There is a need for long-term solutions that a single small team/organization/office cannot provide. And (3) The challenges span multiple sectors, yet no commercial or sustained market-driven solution is available."

One final example aligned to this goal is NSF's support for research on U.S. QIS education and curriculum development with a study of the workforce and education landscape. The QIS workforce and education landscape survey found approximately 8,500 higher education courses related to QIS. The team is exploring how quantum-related coursework is distributed based on discipline, geography, academic level, and institution type. They are also exploring U.S. industry and government needs for jobs in QIS.

From Lab to Market

For NSF, bringing a discovery to market is the ultimate research impact story. As I've talked about NSF's quantum "journey", I have mentioned several examples in which NSF-funded QIS has been spun off into startups and multi-billion-dollar companies. While the NSF has always been deliberate about bringing inventions to market, a suite of programs from the relatively new NSF Directorate for Technology, Innovation and Partnerships (TIP) is accelerating quantum technologies from the lab to the market today.

For example, the NSF Small Business Innovation Research / Small Business Technology Transfer Program (SBIR/STTR) programs have increasingly invested in de-risking the earliest-stage quantum technology ventures, positioning them for specific markets and follow-on funding. Across all technologies, NSF's investment of $1.6 billion in startups and small businesses in recent years has seen more than $32 billion in follow-on funding from venture capital, private industry, and others. Two notable examples in QIS include QC Ware, a leading quantum computing software company, which aims to make quantum computing practical and accessible for enterprises; and Atom Computing, which was recognized by Fast Company as a leading innovator in 2025, highlighting their large-scale neutral atom quantum computers and progress toward fault-tolerant computing, including building upon 1,000+ qubit systems and a recent Microsoft partnership for on-premise quantum solutions.

Additionally, two finalists in the current NSF Regional Innovation Engines (NSF Engines) program competition are focused on advancing QIS in their regions, positioning QIS as the vehicle to drive regional economic growth and job creation, not to mention breakthrough technology output and scaling.

TIP has also initiated new investment frameworks that help researchers straddle the so-called "valley of death" across a range of key technologies. For example, NSF Tech Labs, which will invest in independent research organizations, will provide transdisciplinary teams of researchers with a several-years period of milestone-based funding to harden and mature platform technologies. While NSF awaits feedback to the associated Request for Information on NSF Tech Labs, quantum technologies could well surface as a future priority of this initiative.

Partnerships

As mentioned earlier, the NQI recognized that progress in QIS depends on our shared long-term vision. No single agency, sector, or institution can build the quantum future alone. NSF is proud to partner, directly or indirectly, with other NQI agencies. Some recent interagency partnership examples include: A joint solicitation with the Air Force Research Laboratory seeking to bridge the fundamental science and technology gap in designing materials and devices with specific functionality aimed at quantum sensing, and a partnership with the National Institutes of Health National Institute of Biomedical Imaging and Bioengineering to engage NSF-funded QIS researchers to extend their research on quantum sensing toward biomedical and clinical applications.

We also have several indirect partnerships and collaborations, such as with NIST on the JILA Physics Frontier Center mentioned earlier, and the participation of DOE, NIST, and NASA laboratories as key partners in the QLCIs and the NQVL program.

Access to research infrastructure is another example of interagency collaboration, whereby researchers can access the infrastructure of a partner agency to advance their research. This synergistic leveraging of resources typically takes place at a National Lab or at a university.

International cooperation in quantum research with partners that share U.S. goals advances U.S. leadership in this critical field by leveraging complementary international expertise, research infrastructure, and talent. NSF has a suite of mechanisms to support international quantum collaborations. Since 2019, NSF has awarded over 50 relevant projects with NSF funding the U.S. research team and counterpart agencies in like-minded countries funding the collaborating researchers in its country. For example, in 2025 NSF and UK Research and Innovation (UKRI) announced eight joint awards in quantum chemistry: NSF invested $4.7 million, while UKRI contributed approximately $5.6 million (£4.2 million), effectively amplifying the overall research effort.

Finally, later this week, NSF will be hosting a convening with the private sector, bringing together other federal agencies as well as more than a dozen leading QIS companies to discuss opportunities for potential collaboration. This convening will be a step in the direction of better leveraging multisector expertise and resources to accelerate advances by the interagency, including NSF, and the private sector at the frontiers of QIS.

Conclusion

We have seen incredible advances in artificial intelligence in the last few years; however, it took decades to develop the breakthroughs necessary to mature and translate the technology into the half-trillion-dollar market that it is today. As we have seen, several important breakthroughs in the past few decades have brought us to an inflection point on QIS. As with AI a few years ago, we may now be a few breakthroughs away from a major transformation. However, there are still several technological hurdles to overcome before we can build a large-scale quantum computer.

Looking to the future, NSF funded research teams can continue to de-risk progress toward the overarching goal by undertaking targeted, nimble, research tasks that deliver results needed for developing a large-scale quantum platform for science. NSF will continue to launch new programs, new projects, new workshops, and new coordination efforts to de-risk this work. NSF-funded researchers can engage in high-risk/high-payoff research to prove out viable pathways. As I have shared, NSF supports this process with testbeds, centers, and agile, right-sized efforts each with a critical mass of experts. NSF is poised to continue funding research leaders to discover new applications and new ways to demonstrate and harness quantum advantage.

By pursuing multiple platforms we can accelerate the development of an integrated quantum environment. Such an environment would entail a system of quantum technology that works together as a coherent system: sensors, computers, networks, and algorithms. We may eventually see a quantum motherboard, analogous to the motherboard in your laptop computer, to connect different components which use different hardware for different functionality. Perhaps superconducting qubits for quantum processing units (QPU) will be connected to neutral atoms or trapped ions for longer-lived quantum memory, and networked with photonic interfaces and transduction for a quantum internet to connect the devices.

Akin to how the internet — born from federally-funded fundamental research projects — enabled technology and commerce that has strengthened America, an integrated quantum environment could one day support applications that are greater than the sum of their parts, and beyond what we might now be able to imagine.

The 2018 NQIA recognized that to win the global race for a quantum technology future, it must be a whole-of-government effort. The NQIA provided a solid foundation to win that race. It enabled NSF to play to our strengths by leveraging a collaborative multidisciplinary approach to pioneer new applications, accelerate and de-risk the enterprise through fundamental research, and to fuel groundbreaking discoveries, accelerate translational solutions, and support the U.S. STEM talent of today and tomorrow, reaching 350,000 researchers, entrepreneurs, students, and teachers in an average year. NSF is committed to accelerating our efforts, alongside our partners across the interagency and in collaboration with Congress and this Committee.

Thank you for the opportunity to appear before you today. I look forward to your questions.