September 30, 2021

Re: RFI Response Access to Quantum Systems

Dear Mr. Binkley,

On behalf of the Center for Data Innovation (datainnovation.org), we are pleased to submit comments in response to the Department of Energy (DOE) on its request for information (RFI) on a roadmap to provide researchers access to quantum systems.[1]

The Center for Data Innovation is the leading think tank studying the intersection of data, technology, and public policy. With staff in Washington, D.C., and Brussels, the Center formulates and promotes pragmatic public policies designed to maximize the benefits of data-driven innovation in the public and private sectors. It educates policymakers and the public about the opportunities and challenges associated with data, as well as important data-related technology trends. The Center is a non-profit, non-partisan research institute affiliated with the Information Technology and Innovation Foundation.

OVERVIEW

As explained in the RFI, Congress has requested DOE to develop a roadmap to provide researchers access to quantum systems so as "to enhance the U.S. quantum research enterprise, stimulate the fledgling U.S. quantum computing industry, educate the future quantum computing workforce, and accelerate advancement of quantum computer capabilities." [2]

These goals are laudable and boosting access to quantum systems for academic researchers will help toward achieving them. However, to ensure researchers can use these systems to be more productive and innovate at a higher rate than their competitors, they will also need access to high-quality data and sufficient user support. DOE's roadmap should not only focus on hardware, but comprehensively consider all the research resources individuals will need and how it can support providing access to them all. To ensure the broadest range of qualified researchers, including those at Minority-Serving Institutions (MSIs), can access these resources, DOE should prioritize creating a national quantum computing research cloud that provides academic researchers with affordable access to high-end quantum computing infrastructure.

[1] "Request for Information: Access to Quantum Systems," Federal Register, August 16, 2021, https://www.federalregister.gov/documents/2021/08/16/2021-17520/request-for-information-access-to-quantum-systems.
[2] Ibid.

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We offer comments on the following questions to inform the development of DOE's roadmap.

1. What role, if any, should Federal agencies play in mediating, facilitating, or coordinating access to non-Federal quantum systems?..3
2. What mechanisms should be considered to assure access to quantum systems to the broadest possible user base including under-represented institutions and populations?...4
3. With respect to access to various types of quantum systems, how do near-term and longer-term priorities differ?..5
4. What are the needs for user support to make effective use of access to quantum systems?...7

Please find our responses to the relevant questions in the document below.

Sincerely,

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(1) What role, if any, should Federal agencies play in mediating, facilitating, or coordinating access to non-Federal quantum systems?

The federal government should facilitate affordable access to quantum systems for academic researchers to conduct foundational research the private sector won't do. The private sector is not sufficiently incentivized to conduct fundamental research because they are almost never able to retain all the benefits of that research; it spills over into the knowledge commons and competitors are able to capitalize on it. University-based research in quantum computing is therefore crucial to expanding the knowledge pool from which firms draw the information necessary to conduct later-stage R&D, and ultimately bring innovations to the market.

The proposed Quantum User Expansion for Science and Technology Program (QUEST Act of 2020), which calls on DOE to create a competitive, merit-based program to provide funding for academic researchers to use commercial quantum computing hardware and clouds, is a valuable step toward accelerating progress in quantum information science.[3] But to "stimulate the fledgling U.S. quantum computing industry, educate the future quantum computing workforce, and accelerate advancement of quantum computer capabilities" as the RFI notes, researchers will need more than just access to computing systems—they will need access to high-quality data, educational tools, and user support as well.

Most important is access to data. Researchers cannot solve real-world problems if they do not have access to sufficient real-world data. Consider, for example, that many of the existing applications for quantum computing technology relate to transportation optimization, which rely on mobility data. The best mobility data is often held by private companies such as Facebook, Apple, or Google, and access to public data on mobility differs across cities and states. The U.S. Department of Transportation (DOT) should establish a platform that aggregates and centralizes mobility data across cities, to which public and private players could contribute. Portugal's Centre for Excellence and Innovation in the Automotive Industry has done something similar with its mobi.me system, an integrated platform that connects all types of real-time mobility data into one place, which has helped the country become one of the leading users of quantum computing technology for optimizing traffic.

This example illustrates that the role of federal agencies is not only to mediate, facilitate, or coordinate access to quantum systems but to quantum research infrastructure as a whole. It would be useful for DOE to look to the National AI Research Resource (NAIRR) Task Force, which is developing a roadmap for a shared research infrastructure for AI. The NAIRR is

[3] QUEST Act of 2020, H.R. 8303 116th Cong. (2019).

envisioned as "a shared computing and data infrastructure that would provide AI researchers and students across scientific fields with access to a holistic advanced computing ecosystem."[4] Notably, in its workshops the NAIRR Task Force has inquired whether it should incorporate resources for quantum computing and other quantum technologies. As we wrote in our comments to OSTP and NSF, while AI and quantum differ, the crux of the problem is the same: How can the United States provide academic researchers with affordable access to high-end computing resources and high-quality data in a secure environment?[5] Rather than reinventing the wheel, DOE should work with OSTP and NSF to expand the scope of the NAIRR to include additional resources to support quantum research. This would enable quantum researchers to also benefit from using the data infrastructure the NAIRR would include.

(2) What mechanisms should be considered to assure access to quantum systems to the broadest possible user base including under-represented institutions and populations?

To ensure as many qualified academic researchers as possible have access to quantum research resources, DOE should consider creating a national quantum research cloud that provides academic researchers with affordable access to high-end quantum computing infrastructure.[6] DOE should broaden access to quantum computing by ensuring Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) have equitable access to it.

Not all quantum technologies may be right for the cloud, such as quantum sensors or quantum metrology, but cloud computing has proven it can provide significant value in cost, productivity, and agility when it comes to quantum computing. Indeed, most academic researchers access quantum computers through quantum clouds—services that provide remote access to quantum systems through existing Internet infrastructure. Companies such as Amazon and Microsoft have already begun to make access to quantum computers available through their quantum computing-as-a-service (QCaaS) offerings, which are fully managed services that enable researchers and developers to begin experimenting with systems from multiple quantum hardware providers in a single place.

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[4] "Request for Information (RFI) on an Implementation Plan for a National Artificial Intelligence Research Resource", Federal Register, July 23, 2021, https://www.federalregister.gov/documents/2021/07/23/2021-15660/request-for-information-rfi-on-an-implementation-plan-for-a-national-artificial-intelligence.

[5] Hodan Omaar and Daniel Castro, "Comments to OSTP and NSF on a National AI Research Resource (NAIRR)," September 28, 2021, https://datainnovation.org/2021/09/comments-to-the-ostp-and-nsf-on-a-national-ai-research-resource-nairr/.

[6] Hodan Omaar, "The Case for a National Quantum Computing Research Task Force in the United States," (Center for Data Innovation, June 2021), https://datainnovation.org/2021/06/the-case-for-a-national-quantum-computing-research-task-force-in-the-united-states/.

By developing a national quantum computing research cloud—just like the national AI research cloud that will likely be included in the NAIRR—the federal government can help ensure as many academic researchers as possible have access to a diverse portfolio of quantum computing architectures. Furthermore, DOE could implement a practice that permits researchers to request an allocation of staff time along with access to a quantum system. This will be particularly useful for MSIs, which typically do not have a central body responsible acting as a point of contact for novel computing expertise.

Finally, a national quantum research cloud would make it easier for universities who want to use quantum computers to develop their curricula and support teaching. All universities, including MSIs, should have access to systems they can use to educate undergraduate and graduate students, which may not be best distributed through a competitive grant program like QUEST.

(3) With respect to access to various types of quantum systems, how do near-term and longer-term priorities differ?

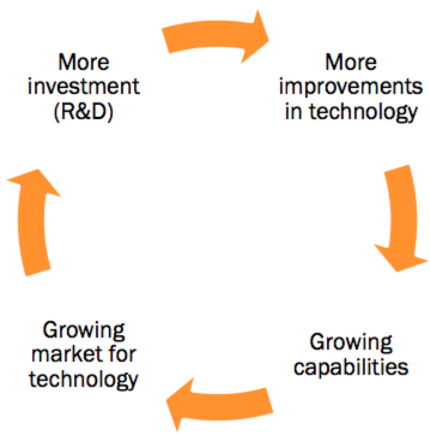
As we explore in our 2021 report "*Why the United States Needs to Invest in Near-Term Quantum Computing Applications*," the long-term and short-term priorities for quantum computers are different but interrelated.[7]

On one hand, quantum computers have significant national security implications in the long-term. Even though many scientists find it unlikely that a large-scale, fault-tolerant quantum computer will be developed in the next decade, if one were to be developed, such a system could theoretically break current encryption protocols, such as those used to secure financial transactions, private emails, and national security communiques. Addressing the implications of quantum computing capabilities over the long-term will require thoughtful consideration and strategic planning.

However, the development of large-scale quantum computers depends on the ability to scale the number of qubits in a system, much like modern classical computers have depended on increases to the number of transistors per integrated circuit. Historically, growth in computational power resulted from a virtuous cycle wherein better technology generated more revenue, which companies reinvested in R&D, which in turn attracted both new talent and companies that had helped bring the technology to the next level (Figure 1).

[7] Hodan Omaar, "Why the United States Needs to Support Near-Term Quantum Computing Applications," (Center for Data Innovation, April 2021), https://www2.datainnovation.org/2021-quantum-computing.pdf.

Figure 1: Virtuous cycle for scaling a new technology.[8]



In order to begin such a virtuous cycle for quantum computing technologies, the key will be to create a growing market for the near-term applications of quantum computers currently under development, which in turn depends on a vibrant ecosystem of academic, government, and commercial actors.

The federal government has a central role to play in ensuring quantum computing technologies have sufficient economic impact to bootstrap a virtuous cycle of investment, as it did with the development of integrated circuits. As an early adopter and procurer of nascent information communication technologies (ICTs), the U.S. government has historically been indispensable in signaling the benefits of using new ICTs and, in many cases, has driven their prices down to a point that made their application by industry feasible.

DOE should focus a greater portion of its investments in quantum computing on near-term applications. As part of the National Quantum Initiative Act passed in 2018, the Department of Energy (DOE) is awarding $625 million between 2020 and 2025 to its Argonne, Brookhaven, Fermi, Oak Ridge, and Lawrence Berkeley National Laboratories.[9] Each laboratory is charged with creating a quantum information research hub "to conduct basic

[8] National Academies of Sciences, Engineering, and Medicine (NASEM) 2019, Quantum Computing: Progress and Prospects, (Washington, D.C.: The National Academies Press), 5, https://doi.org/10.17226/25196.

[9] "White House Office of Technology Policy, National Science Foundation and Department of Energy Announce Over $1 Billion in Awards for Artificial Intelligence and Quantum Information Science Research Institutes," Energy.gov website, last modified August 26, 2020, https://www.energy.gov/articles/white-house-office-technology-policynational-science-foundation-and-department-energy.

research to accelerate scientific breakthroughs in quantum information science (QIS) and technology."[10] Specifically, DOE's QIS labs will be focusing on three areas: supporting fundamental science that underpins quantum computing, simulation, communication, and sensing; creating tools, equipment, and instrumentation that go beyond what was previously imaginable; and establishing DOE community resources that enable the QIS ecosystem to innovate. These focuses, however, overlook the key driver of a virtuous cycle: prioritizing technology transfer and commercialization of quantum computing technologies.

(4) What are the needs for user support to make effective use of access to quantum systems?

As part of a national quantum computing research cloud, DOE should prioritize the development of a service-oriented architecture, which would integrate access to diverse quantum systems by providing users a common interface and a set of standard protocols for them to efficiently access the tools they need.

The diversity of quantum computing models and architectures can make it difficult for researchers to know which systems are best for them to use. For instance, several companies such as IBM, Google, Intel, and Rigetti, manufacture quantum chips that implement the gate-based mode (referring to the quantum computing approach of breaking a computation down into a sequence of gates). But the architectures of the chips differ in several aspects, such as the number of qubits, the links between them, and their error rates.

In addition, many vendors of these systems provide their own proprietary software development kits (SDKs), which are the sets of libraries, processes, tools, and guides that allow developers to create software applications that can execute circuits on quantum chips. For example, IBM has created its own SDK called Qiskit, Rigetti has developed Forest SDK, and Google has developed Cirq. While some hardware-agnostic tools that enable developers to create software that will work on multiple quantum computers do exist, for the most part, the use of proprietary SDKs means software developers have to choose which quantum chip they want to use before they start developing. And because current quantum computers have limited capabilities, choosing the best one for a particular task means developers must have significant technical knowledge about a chip's architecture and the company's SDK. Developing a service-oriented architecture to help users navigate the quantum system landscape might help address some of these challenges.

[10] National Quantum Initiative Act, H.R.6227, 115th Cong. (2018).