Special Topic: Quantum Computing

The Promise and Potential of Quantum Computing

Quantum computing exploits the laws of quantum mechanics to provide a new basis for computation. Rather than relying on a binary system to store data using 1s and 0s, quantum computers store information using quantum bits (qubits), which can encode both values simultaneously. Quantum computers can also "entangle" multiple qubits, which permits computations on one qubit to affect many others and potentially solve problems exponentially faster than conventional computers. It may open doors to solving problems that we currently consider intractable.[1,2] For example, future quantum computers could theoretically analyze massive datasets (e.g., real-time video of Earth's surface) that would be too large for conventional devices to store and manage or could design new materials by simulating complex molecular behavior.[3]

The scale of future improvements that quantum computing could bring is leaps and bounds beyond speeds currently experienced. The potential applications of quantum computing — systems optimization, machine learning and materials design — could unlock products, services and capabilities across a wide range of industries, including finance, aerospace and defense, telecommunications, and health care and pharmaceuticals.[4] Realizing this promise will require the ability to apply quantum algorithms to commercial activities, despite the long path of technical challenges needed to develop these capabilities.

The State of the Quantum Computing Landscape

U.S. companies and government agencies have actively pursued groundbreaking applications of quantum computing.[5] U.S. strength in quantum research is bolstered by a relatively small number of researchers providing multidisciplinary expertise. Top-tier U.S. research institutions also drive basic research advances, often in collaboration with industry.[6] As a result, the past few years have seen dramatic advances in quantum computing technology and growth in small companies seeking to establish a presence in the field.[7]

Globally, the competitive landscape in quantum computing research is marked by consistent planning and investment on the national level. In total, governments have already provided $2.2 billion in funding for quantum computing research.[8] Notably, China has pledged $20 billion for a national lab for quantum science (scheduled for 2020), and the European Union is pursuing a "quantum flagship" program that promises to invest a billion euros over 10 years from public and private sources.[9] Maintaining U.S. momentum and leadership in quantum computing will require vigorously and strategically addressing key challenges while sustaining long-term investment streams.

Recent legislation takes an important step toward this type of sustained commitment to collaboration, building momentum on key policy priorities articulated in the White House's National Strategic Overview for Quantum Information Science.[10] Among other actions, the recently passed National Quantum Initiative Act funds the establishment of national research centers under the Department of Energy, basic research and education programs at the National Science Foundation, and a coordinated ten-year National Quantum Initiative Program for research and development (R&D) efforts.

Looking to the Future of Quantum Computing

As is the case for most advanced technologies, quantum computing research can best flourish when supported by collaborative research networks, a shared commitment to and investment in a long-term vision, and the promise of varied and valuable applications. A strategic national effort around quantum computing should include coordinated actions to support a complex research landscape and address the cross-cutting challenges and implications associated with these advances. Policymakers should work with quantum computing researchers, industry members and other stakeholders to:

BR

1. **Attract and develop talent in quantum computing.** In a field in which, according to reports, the global count of leading researchers does not exceed 1,000, investment in conditions that attract and foster talent is critical.[11] By encouraging the development of the discipline, broadening engagement and investing in relevant educational resources, the government and other stakeholders can bolster human capital in the field. These efforts must extend across a wide range of age groups and experiences. Retraining technically capable workers who are mid-career is as important to the success of the field as the education of students in high schools, colleges and universities.

2. **Promote international collaboration that advances the field.** As outlined in the National Strategic Overview for Quantum Information Science, the United States should increase international cooperation on quantum research, as well as take steps to strategically monitor and guide the development of the international quantum computing landscape. The United States also should take steps to ensure that fair and ethical business practices, such as the recognition of intellectual property, are upheld across the international quantum computing landscape.

3. **Consider the national security and defense implications.** Quantum computing promises to drastically alter the national security landscape as technology evolves that can overpower current encryption methods. The United States should invest in quantum leadership, as well as in research that prepares government and critical infrastructure providers to defend themselves in a post-encryption world.

4. **Facilitate collaboration around mid-term applications and long-term goals.** Identifying clear goals and highlighting shared aspirations for quantum computing development help maintain and build on existing momentum. This collaborative effort includes setting goals for applying quantum algorithms to commercially useful problems and developing a national network of quantum computers and computational centers.

5. **Sustain and build on the R&D funding stream for quantum computing research initiatives.** The federal government should continue to prioritize R&D investment in quantum computing research, building on the momentum of the National Quantum Initiative Act. This effort includes ensuring long-term, robust funding for the newly established National Quantum Information Science Research Centers and research program under the Departments of Energy, Commerce and Defense.

ENDNOTES

1 U.S. House of Representatives Committee on Energy and Commerce. (2018, May 16). Briefing for Committee hearing "Disrupter Series: Quantum Computing."

2 Greenemeier, L. (2018, May 30). How close are we — really — to building a quantum computer? Scientific American.

3 Monroe, C. (2018, May 18). Statement to the U.S. Committee on Energy and Commerce Subcommittee on Digital Commerce and Consumer Protection: Hearing on Disruptor Series: Quantum Computing.

4 Schatsky, D., & Puliyakodil, R. K. (2017, April 26). From fantasy to reality: Quantum computing is coming to the marketplace. Deloitte.

5 Herman, A. (2018, May 21). Winning the race in quantum computing. Hudson Institute.

6 Examples of public- and private-sector collaborations include the IBM Q Network, the Alliance for Quantum Technologies (led by AT&T and the California Institute of Technology), the Google Quantum A.I. Lab (partnered with UC Santa Barbara), and the USC-Lockheed Martin Quantum Computation Center and University of Maryland Quantum Engineering Center.

7 Accenture. *Think beyond ones and zeros: Quantum computing now.*

8 Schatsky, D., & Puliyakodil, R. K. (2017, April 26). From fantasy to reality: Quantum computing is coming to the marketplace. Deloitte.

9 U.S. House of Representatives Committee on Energy and Commerce. (2018, May 16). Briefing for Committee hearing "Disrupter Series: Quantum Computing."

10 Subcommittee on Quantum Information Science, Committee on Science of the National Science and Technology Council. (2018, September). *National strategic overview for quantum information science. Executive Office of the President of the United States.*

11 Metz, C. (2018, October 18). The next tech talent shortage: Quantum computing researchers. *The New York Times.*