Google

Google Quantum AI

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Chairman Babin, Ranking Member Lofgren, and distinguished Members of the Committee; thank you for the opportunity to appear before you today. My name is Charina Chou, and I am Director and Chief Operating Officer for Google Quantum AI. We appreciate the House Committee on Science, Space, and Technology holding this important hearing, and we look forward to explaining Google's work in the field of quantum technology. Quantum computers can solve problems that supercomputers and artificial intelligence cannot. The National Quantum Initiative has helped make this technology a reality, and its reauthorization will help ensure continued U.S. leadership.

The United States leads the development of quantum computing, and Google has the most advanced, state-of-the-art quantum computing effort anywhere in the world. Our quantum chips are made in the USA. We proudly make our chips at a dedicated superconducting fabrication facility – one of the few in the world – in Santa Barbara, California. All of our quantum computing technology is located in our California quantum computing laboratories.

We believe quantum computers can help shape a brighter future and solve otherwise impossible problems in the fields of drug discovery, industrial chemistry, energy, and more. We are optimistic that within five years we will see real-world applications that are possible only on quantum computers. Quantum computing will have far-ranging impacts for the economy and national security, with an expected economic value of the future quantum computing industry in the range of hundreds of billions of dollars, and many applications that are directly relevant for national security.

Today, I will highlight: (1) the fundamentals of quantum computing, including American-made qubits; (2) future real-world applications to solve problems; and (3) Google Quantum AI, the Willow chip, and U.S. leadership.

Quantum Computing & American-Made Chips

Quantum computers are extraordinary. They harness the power of quantum mechanical properties that occur in nature, and unlike traditional computers that find solutions one by one, quantum computers can explore multiple solutions simultaneously.

Quantum computing is an entirely new method of computing. Most people are familiar with classical computing: the binary digits (or "bits") that can be either 1's or 0's, which power everything from graphing calculators to massive data centers and underlie almost all of the digital innovation from the past half-century. Quantum computing is different. Rather than using classical bits, quantum computing uses quantum bits, or "qubits."

Qubits behave according to the laws of quantum physics. Instead of being confined to the "either/or" of binary 1's and 0's, they can exist as a blend of both. Qubits can store information in superposition (multiple states at the same time) of 0 and 1. They can also be entangled with each other to make even more complex combinations — i.e. the state of qubits can be correlated, so two qubits can be in a blend of 00, 01, 10 and 11 at the same time. Entangling many qubits together allows a vast number of states they can be in and provides significant computational power. Those two special properties of superposition and entanglement provide quantum computers with the superpower to solve some of the most difficult problems much, much faster than regular, classical computers can.

Unlike classical computing chips — which are produced by a huge and well-established industry — quantum is an entirely new mode of computing that, at Google, we make our own qubits in-house with superconducting integrated circuits. Our fabrication facility is located in Santa Barbara, CA.

Chips are just one component in a complex system. Building a quantum computer is an ambitious task that no one company or organization can achieve alone. While Google and others have made impressive progress in quantum computing in recent years, quantum computing is still a nascent industry and we need to work across sectors to advance its potential. For example, our qubits are composed of superconducting materials patterned into special nonlinear elements called Josephson Junctions. These superconducting integrated circuits are advanced technologies that result from the unique ecosystem in the United States involving government, academia, and industry. The foundational work for Josephson Junctions was performed by the National Institute of Standards and Technology (NIST) over thirty years ago. Our hardware effort grew from a group at the University of California, Santa Barbara, with critical funding coming from the private sector, as well as from the Intelligence Advanced Research Projects Agency, the National Nanotechnology Initiative, and the National Quantum Initiative. In total, Google Quantum AI collaborates with more than 100 partners in the government, academia, and the private sector.

Solving Real-World Problems

Google is committed to building state-of-the-art technology and sharing its benefits to improve the lives of billions of people. We have yet to discover even a small portion of the ways quantum computing will benefit society in the future, but we know it has the potential to solve problems we once thought were unsolvable. For example, superposition and entanglement provide quantum computers with the ability to discover solutions that supercomputers and artificial intelligence cannot. Below are some examples of the role quantum computing can potentially play in addressing real world challenges:

- **Pharmaceuticals.** Drug molecules must interact selectively with molecules inside the body. To simulate the behavior of cytochrome P450, a family of enzymes largely responsible for drug metabolism and patients' response to drugs, classical computers would require colossal amounts of computing power. With quantum computers, this effort could be accomplished far more efficiently, leading to important disease-fighting innovations.
- **Chemicals and materials industries.** Quantum computing could inform the design of more efficient batteries for electric cars and noncorrosive elements for ships.
- **Fusion energy.** Fusion power offers the promise of abundant renewable energy, but it has yet to be realized at scale. Designing the necessary reactors relies on computational models to understand materials under extreme fusion conditions. However, current models lack accuracy, often failing to match real-world results, and demand billions of CPU hours. In collaboration with Sandia National Laboratories, our researchers showed that a quantum algorithm run on a quantum computer could more efficiently simulate the mechanisms needed for sustained fusion reactions, which could ultimately help make fusion energy a reality.
- **AI**. Quantum simulations will also provide an extremely valuable trove of data for classical AI to learn from in order to better model the physical world. We have also shown that machine learning from quantum data — i.e., from quantum sensors or magnetic fields — will only be possible using a quantum computer. Quantum computers can also provide exponential advantages for optimization and other classical learning problems.

Even today, our early quantum computers are already being used to make interesting physics discoveries. For example, we have used them to test theories of how particles interact. And we are optimistic that within the next five years we will see real-world applications that are only possible on quantum computers.

Google Quantum AI, the Willow Chip, and U.S. Leadership

At Google Quantum AI, we believe the full potential of quantum computing will be unlocked with a large-scale computer capable of complex computations, and we aim to build this computer. In 2019, we demonstrated "beyond classical" performance of a quantum computer, showing that quantum computers could outperform classical computers on a benchmark task. In 2023, we demonstrated that error correction — which is critical to real-world applications — can improve as quantum processors are scaled to larger numbers of qubits.

Last year we built on both our previous results, achieving two breakthrough feats with our 105-qubit Willow chip. First, Willow is capable of running a benchmark task in a few minutes which would take one of today's fastest supercomputers 10 septillion years — a number that vastly exceeds the age of the Universe. Second, Willow demonstrated "below threshold" error correction, solving a 30-year problem in the field that is critical to real-world applications. We believe Willow's performance is a strong sign that useful, very large quantum computers can indeed be built; and the chip is a product of Google's long-standing and substantial investments in building quantum technology.

Our work continues. Our next target is to create a qubit capable of one million computational steps with less than one error. And as we look further ahead to unlocking the full application potential of quantum computers, we will need to scale our technology from chips with about 100 physical qubits, to chips with about one million physical qubits, and significantly improve the quality of our qubits by many orders of magnitude. We are excited about what quantum computing means for the future of Google and the world.

Our vision is that one day, people will use quantum computers alongside classical computers to expand the boundaries of human knowledge and solve some of the world's most complex problems. We believe the Committee's work – and the reauthorization of the National Quantum Initiative – are key to America's continued global leadership in quantum computing. From workforce development and educational initiatives, to cross-sectoral coordination, to basic R&D funding, the efforts of this Committee and the NQI are critical. Reauthorization of the NQI will also send a signal of continued U.S. leadership to the world.

The United States currently leads the world in quantum computing: nearly all of the best quantum computing hardware companies are based in America, spanning all qubit technologies. According to a recent report, U.S. venture capital investments through 2023 were $3.5 billion, more than twice than in any other country – and this does not account for large financial investments at companies like Google. The United States leads the world in computing-related patents, and we are home to 75 academic quantum technology research programs, more than any other country or region. It is vital that the United States continues to lead the development of this technology so we are positioned to leverage future scientific breakthroughs, advance national security, and increase economic output.

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Thank you for convening this important hearing. We look forward to continuing to further American leadership in this transformative space. Thank you.