# What is Quantum Computing?

## Overview

While the private sector is utilizing quantum computing technology, many are pushing for the United States government to focus on the development and deployment of quantum applications and utilize the technology for various public initiatives. Recently, the U.S. Congress has included researching quantum computing technology in numerous bills including the U.S. Innovation and Competition Act, Endless Frontiers Act, QUEST, National Defense Authorization Act and Appropriations. As the quantum computing hardware and software industry continues to expand, there are opportunities for expansion and collaboration between the public and private sector to work on near-term applications.

## What is Quantum Computing?

Classical computing is binary computing used by large scale multi-purpose computers and devices. Information is stored in bits that are represented by either a 0 (off) or a 1 (on). Operations that are not feasible in classical computing can be performed with a quantum computer.

Quantum computing is a type of non-classical computing operating on the quantum states of subatomic particles utilizing quantum physics. Quantum bits (qubits) can represent all possible values simultaneously (superposition) until reading, unlike the traditional 0 and 1 of classical computers. Systems can link qubits with other qubits, called entanglement, to provide a system where quantum algorithms manipulate linked qubits in their undetermined, entangled state. This process is then able to address many problems with vast combinatorial complexity.

Some quantum computers have to be at a temperature of -273 °C (-459 °F) with hardly any atmospheric pressure and isolated from Earth's magnetic field. There are numerous foundational approaches to quantum computing hardware such as gate, annealing, and topological quantum computing systems. There are also a variety of quantum computing chip fabrications including superconducting, ion traps, silicon, photonics, and others.

Recent innovation in the quantum industry has led to progress in the number and robustness of the qubits and the creation of hybrid solvers that provide the benefit of both quantum and classical computing power. This allows today's quantum technology, and hybrid applications, to tackle many large programs. Some of today's quantum computing systems are beginning to solve problems much faster than classical computers, and in some cases, providing solutions beyond the abilities of today's classical computers, while also consuming less energy. Lastly, nearly all quantum hardware systems are available via cloud access, that break down barriers to accessing the computational power of the systems. Quantum cloud access increases accessibility for those conducting research, as well as for

## Center Forward Basics

Center Forward brings together members of Congress, not-for profits, academic experts, trade associations, corporations and unions to find common ground. Our mission: to give centrist allies the information they need to craft common sense solutions, and provide those allies the support they need to turn those ideas into results.

In order to meet our challenges we need to put aside the partisan bickering that has gridlocked Washington and come together to find common sense solutions.

For more information, please visit www.center-forward.org

## Key Terms

- **Classical computer:** information is stored in bits that are represented logically by either a 0 or a 1; used by large scale multi-purpose computers and devices.
- **Qubits (quantum bits):** can store a 0, a 1, both 0 and 1, or an infinite number of values in between; qubits enable quantum computers to do things traditional computers cannot.
- **Superposition:** qubits use superposition to represent multiple states (multiple numeric values) simultaneously.
- **Entanglements:** qubs are correlated in such a way that changing the state of one qubit instantaneously changes the state of another in a predictable way.

those who are currently working to solve key near-term problems.

## Practical Applications

There are many large-scale projects that can benefit from today's quantum computing and hybrid solver systems. Historically in the U.S. government, the Department of Energy, Department of Commerce, the National Science Foundation, and the Department of Defense have traditionally led research efforts related to quantum technology. Utilizing this technology in the future could help address problems related to emergency response, grid resiliency, broadband roll out, predictive fleet maintenance, and cybersecurity.

Many countries have funded projects that utilize today's quantum computing technology. In April 2021, the Australian Department of Defense announced they were using quantum computing to optimize how autonomous vehicles could resupply army forces from a central base. Additionally, both Canada and the United Kingdom have announced challenges to fund quantum computing related projects and are looking at developing quantum applications for various industries.

Other countries are using quantum computing applications for projects related to infrastructure, sustainability, telecommunications, and emergency responses. In Lisbon, Portugal, Volkswagen launched the first pilot project for bus and traffic optimization using a quantum computer. This system reduced passengers' travel times and improved traffic flow. Groovenauts, Inc., a software company in Japan, worked with Mitsubishi Estate Co to optimize the collection and transportation of waste in Tokyo. This project led to reduced $CO_2$ emissions. In Italy, Telecom Italia became the first telecommunications operator in Europe to use quantum computing algorithms for planning its mobile networks. This has led to addressing complex business problems, cost saving, and 5G roll out.

The online access and hybrid applications provide an inflexion point which provides the ability to tackle larger problems at commercial and government scale.

## The Future of Quantum Computing

Current quantum computer applications can solve problems in areas such as health care, manufacturing, transportation, and sustainability. Governments and various industries can develop dedicated quantum application programs that advance technologies and solidify U.S. economic competitiveness. Solutions to increasing the United States development and deployment of quantum applications include developing a government program dedicated to near-term usage with a focus on new, emerging technologies. Others suggest it is important to provide greater financial access to quantum computing systems to help researchers, start-ups, and other groups and provide workforce development for this industry.

## Links to Other Resources

- Advanced Technology Academic Research Center – Applied Quantum Computing for Today's Military
- Australian Army Research Center – Launch of the Army Quantum Technology Roadmap
- Center for Data Innovation – Why the United States Needs to Support Near-Term Quantum Computing Applications
- D-Wave Systems – As the U.S. Discusses Infrastructure, Can Practical Quantum Computing Play a Role?
- D-Wave Systems – Groovenauts and Mitsubishi Estate: Creating Sustainable Cities through Waste Collection Optimization
- Gartner – Quantum Computing
- Government of Canada – Quantum Computing-as-a-Service

- National Security Telecommunications Advisory Committee – NSTAC Report to the President on Communications Resiliency
- The Quantum Insider – How Quantum Computers Could Be Used to Thwart a Future Pandemic
- TIM Group – TIM is the first operator in Europe to use quantum computing live on its mobile networks (4.5G and 5G)
- Volkswagen – Volkswagen optimizes traffic flow with quantum computers