



# Defense Primer: Quantum Technology

Quantum technology translates the principles of quantum physics into technological applications. Quantum technology has not yet reached maturity for most applications; however, it could hold significant implications for the future of military sensing, encryption, and communications, as well as for congressional oversight, authorizations, and appropriations.

## Key Concepts in Quantum Technology

Quantum applications rely on a number of key concepts, including superposition, quantum bits (qubits), and entanglement. *Superposition* refers to the ability of quantum systems to exist in two or more states simultaneously. A *qubit* is a computing unit that leverages the principle of superposition to encode information. (A classical computer encodes information in bits that can represent binary states of either 0 or 1, whereas a quantum computer encodes information in qubits, each of which can represent 0, 1, or a combination of 0 and 1 at the same time. Thus, the power of a quantum computer increases exponentially with the addition of each qubit.)

*Entanglement* is defined by the National Academy of Sciences (NAS) as a property in which “two or more quantum objects in a system can be intrinsically linked such that measurement of one dictates the possible measurement outcomes for another, regardless of how far apart the two objects are.” Entanglement underpins a number of potential military applications of quantum technology. Both superposition and entanglement are, however, difficult to sustain due to the fragility of quantum states, which can be disrupted by minute movements, changes in temperature, or other environmental factors.

## Military Applications of Quantum Technology

The Defense Science Board (DSB), an independent Department of Defense (DOD) board of scientific advisors, has concluded that three applications of quantum technology hold the most promise for DOD: quantum sensing, quantum computers, and quantum communications. (DOD is currently “using a secondary Department of War designation” under Executive Order 14347 dated September 5, 2025.) The DSB concluded that quantum radar, hypothesized to be capable of identifying the performance characteristics (e.g., radar cross-section, speed) of objects—including low observable, or stealth, aircraft—“will not provide upgraded capability to DOD.”

### Quantum Sensing

Quantum sensing uses the principles of quantum physics within a sensor. According to the DSB, this is the most mature military application of quantum technologies and is currently “poised for mission use.” Quantum sensing could provide a number of enhanced military capabilities. For example, it could provide alternative positioning,

navigation, and timing options that could in theory allow militaries to continue to operate at full performance in GPS-degraded or GPS-denied environments.

In addition, quantum sensors could potentially be used in an intelligence, surveillance, and reconnaissance (ISR) role. Quantum sensors could enable military personnel to detect underground structures or nuclear materials due to their expected “extreme sensitivity to environmental disturbances.” The sensitivity of quantum sensors could similarly enable militaries to detect electromagnetic emissions, thus enhancing electronic warfare capabilities and potentially assisting in locating concealed adversary forces. On October 3, 2024, Senators Hassan and Blackburn submitted a formal letter to DOD requesting written responses—by November 15, 2024—to a series of questions about the Department’s quantum sensing initiatives, funding, strategy, and coordination efforts.

### Quantum Computers

According to NAS, “quantum computers are the only known model for computing that could offer exponential speedup over today’s computers.” While quantum computers are in a relatively early stage of development (at least 10 years in the future, per DOD’s July 2025 assessment), advances—many of which are driven by the commercial sector—could hold implications for the future of artificial intelligence (AI), encryption, and other disciplines.

For example, some analysts have suggested that quantum computers could enable advances in machine learning, a subfield of AI. (For an explanation of AI- and machine learning-related terms, see CRS Infographic IG10077, *Artificial Intelligence (AI) Taxonomy*, by Laurie Harris and Nora Wells.) Such advances could spur improved pattern recognition and machine-based target identification. This could in turn enable the development of more accurate lethal autonomous weapon systems, or weapons capable of selecting and engaging targets without the need for manual human control or remote operation. AI-enabled quantum computers potentially could be paired with quantum sensors to further enhance military ISR applications.

In addition, quantum computers could potentially decrypt classified or controlled unclassified information stored on encrypted media, allowing adversaries to gain access to sensitive information about U.S. military or intelligence operations. Some analysts note that significant advances in quantum computing would likely be required to break current encryption methods. Their estimates suggest that a quantum computer with around 20 million qubits would be required to break current encryption methods; however, the most advanced quantum computers today generally have no more than around 1,000 qubits.

The practical applications of quantum computers will likely be realized only after improvement in error rates and development of new quantum algorithms, software tools, and hardware. While, as NAS notes, “there is no guarantee that [these technical challenges] will be overcome,” some analysts believe that an initial quantum computer prototype capable of breaking current encryption methods could be developed in the 2030 to 2040 timeframe. For this reason, NAS concludes that “the development, standardization, and deployment of post-quantum cryptography is critical for minimizing the chance of a potential security and privacy disaster.” (Information intercepted prior to the deployment of post-quantum cryptography would not be protected.)

In May 2022, the Biden Administration released *National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems (NSM-10)*, which “directs specific actions for agencies to take as the United States begins the multi-year process of migrating vulnerable computer systems to quantum-resistant cryptography.” NSM-10 notes that the Director of the National Institute of Standards and Technology and the Director of the National Security Agency (NSA) are to develop technical standards for quantum resistant cryptography. NIST released the first tranche of these standards in August 2024. NSA has stated that it “expects the transition to [quantum-resistant] algorithms for [national security systems] to be complete by 2035 in line with NSM-10.”

### Quantum Communications

Quantum communications—excluding quantum key distribution ([QKD], discussed below)—are in a nascent stage of development. Quantum communications could theoretically enable the secure networking of quantum military sensors, computers, and other systems, thus improving performance over that of a single quantum system or classical communications network. Networking could additionally strengthen the robustness of such systems at range, thus expanding the potential environments in which they could be deployed (i.e., outside of the laboratory settings generally required to sustain fragile quantum states). This could significantly expand the military utility of quantum communications.

Quantum key distribution is a subset of quantum communications that uses the principles of quantum physics to encrypt information that is then sent over classical networks. QKD enables secure communications that cannot be covertly intercepted during transmission. (QKD communications can, however, be intercepted at the relay stations currently required for long-distance transmissions.) China is reportedly investing heavily in QKD and completed construction of an approximately 1,250-mile Beijing-Shanghai quantum network in 2016. Nonetheless, the DSB concluded that “QKD has not been implemented with sufficient capability or security to be deployed for DOD mission use.”

### Selected Legislative Activity

Congress has passed numerous provisions related to quantum technology. For example, Section 234 of the FY2019 National Defense Authorization Act (NDAA) (P.L.

115-232), later amended by Section 220 of the FY2020 NDAA (P.L. 116-92) and Section 219 of the FY2024 NDAA (P.L. 118-31), directs the Secretary of Defense—who is currently using a secondary Secretary of War designation under Executive Order 14347—to execute a quantum technology research and development program in coordination with the private sector, international entities, and other government agencies. Section 220 of the FY2020 NDAA additionally authorizes the Secretary of each military department to establish Quantum Information Science (QIS) Research Centers that may “engage with appropriate public and private sector organizations” to advance quantum research. Each of the departments subsequently designated their respective research laboratories as QIS Research Centers.

Section 214 of the FY2021 NDAA (P.L. 116-283) directs the services to compile and annually update a list of technical challenges that quantum computers could potentially address within the next one to three years and to establish programs with small and medium businesses to provide quantum computing capabilities to government, industry, and academic researchers working on these challenges.

Section 220 of the FY2024 NDAA directs DOD to establish a public-private talent exchange program for quantum research, while Section 231 authorizes a DOD pilot program for quantum computing.

Finally, Section 231 of the FY2025 NDAA (P.L. 118-159) directs the Director of the Defense Advanced Research Projects Agency to “establish and carry out [a Quantum Benchmarking Initiative] to rapidly expand and support efforts to evaluate concepts, development plans, and prototypes, components, and subsystems needed to develop a utility-scale quantum computing capability” for DOD. Section 244 directs the Secretary of Defense to develop a strategic plan for quantum technologies within the department.

### Potential Questions for Congress

- What funding level does the current maturity of military applications of quantum technology warrant? To what extent, if at all, should the U.S. government invest in and research technologies that enable quantum military applications (e.g., materials science, fabrication techniques)?
- To what extent, if at all, can commercial advances in quantum technology be leveraged for military applications?
- How mature are U.S. competitor efforts to develop military applications of quantum technologies? To what extent, if at all, could such efforts threaten advanced U.S. military capabilities, such as stealth aircraft?
- What measures, if any, should the United States take to ensure that the quantum workforce is sufficient to support U.S. competitiveness in quantum technology?

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