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# Quantum Computing: Applications, Readiness & Risk

## Where the technology stands, where it fits & how Asia Pacific is preparing

NOVEMBER 2026



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# Introduction

**Quantum computing is producing results that are starting to matter outside the research community.**

Quantum processors are becoming more capable, error-correction techniques are improving, and cloud access means organisations can run workloads without installing their own machines.

The technology is still developing. Current systems have limited computational capacity and relatively high error rates, while many proposed applications have yet to demonstrate a consistent advantage over classical computing. Enterprise experiments are focused on specific computational problems where organisations can evaluate the technology against existing approaches and workloads.

Security is different. Current quantum computers cannot break modern public-key encryption at scale, but attackers can collect encrypted information now and attempt to decrypt it later. For data that needs to remain confidential for many years, organisations need to consider the risk well before a capable quantum computer exists.

Governments are responding with substantial programs covering research, hardware, communications, cybersecurity, and skills. Enterprise activity is more selective, with organisations testing specific applications and assessing where the technology fits their workloads.

The result is a technology with two very different timelines: organisations can experiment with quantum computing today, while some of its most important consequences may only become apparent as the underlying hardware matures.

# Why Quantum, Why Now

**Quantum computing has been discussed for decades, but several developments are bringing it closer to enterprise and national technology agendas.**

Advances in hardware and error correction are extending what quantum systems can do, while cloud access is making experimentation possible without owning quantum hardware.

The timing also reflects growing attention to the areas where quantum computing could have the greatest impact – from optimisation and materials science to drug discovery and cybersecurity. The opportunity is still uncertain, but the decisions around investment, experimentation and security are becoming more immediate.

## What is Changing

### Hardware development is moving beyond qubit counts

Physical qubit counts remain a useful measure of scale, but they do not capture how reliably a system can execute quantum operations or how much computation it can perform. Errors can limit the depth and complexity of circuits that run reliably. Work on logical qubits and error correction has seen progress, including Google's demonstration of below-threshold error correction on its Willow processor and IBM and University of Chicago's 2026 demonstration using 70 logical qubits. Scaling these techniques to the error rates, circuit sizes, and reliability required for larger applications remains a significant engineering challenge.

### Software and cloud access are making experimentation more practical

Organisations can access quantum processors remotely through cloud platforms, develop and test algorithms, and integrate quantum workloads with conventional computing. This allows organisations to explore specific use cases without owning quantum hardware.

### Quantum processors are being integrated into broader computing environments

Quantum systems are being developed as part of hybrid quantum-classical workflows. IBM and RIKEN demonstrated a closed-loop workflow between an IBM Quantum Heron processor and Japan's Fugaku supercomputer, with quantum and classical systems exchanging data during the computation. The workflow used all 152,064 Fugaku compute nodes. This demonstrates how quantum processors can be incorporated into high-performance computing environments, with different systems handling different parts of a workload.

### Commercial activity is broadening

The market now extends beyond quantum processors to include cloud access, software, networking, security, and professional services. Quantum companies are reporting growing commercial revenues and production use of quantum computing services, providing evidence of a developing customer market. The technology remains at an early stage, but commercial activity is extending beyond hardware development.

### Governments are treating quantum as both an economic and security capability

Public programs are funding research, hardware, communications, post-quantum cryptography, infrastructure, and skills, while also supporting commercialisation and domestic supply chains. Security considerations are particularly visible because quantum computing, sensing, and communications have potential defence and national security applications. The US, for example, has tied its 2026 quantum policy to commercialisation, domestic manufacturing, and national security, while the UK's national strategy links quantum to economic growth, resilience, national security, and defence.

## The Quantum Technology Landscape

### Hardware and full-stack providers

Companies including IBM, Google, IonQ, Quantinuum, Rigetti, D-Wave, and PsiQuantum are developing different approaches to quantum computing, including superconducting, trapped-ion, neutral-atom, annealing, and photonic systems. These approaches differ in how qubits are created and controlled, how errors are managed, and how systems can be scaled.

### Cloud platforms

Platforms such as AWS Braket and Microsoft Azure Quantum provide access to quantum processors from multiple providers through a common cloud environment. This allows organisations to test workloads across different hardware without establishing separate infrastructure or access arrangements for each system.

### Software and control

A separate layer is developing around the software used to design, compile, execute, control, and improve quantum workloads. Companies such as Q-CTRL and Classiq provide tools for quantum control, algorithm development, and execution, while NVIDIA's CUDA-Q supports hybrid quantum-classical application development. These tools connect quantum processors with the software and classical computing infrastructure needed to use them.

### National quantum platforms

Governments are also building public infrastructure around quantum computing. China Telecom's Tianyan platform provides cloud access to a cluster of superconducting quantum computers, while the UK's National Quantum Computing Centre provides national research infrastructure. In the US, the National Quantum Initiative connects federal agencies, research centres, national laboratories, and industry through a coordinated national program. These initiatives give governments a role in building research capacity, infrastructure, and domestic expertise beyond what commercial providers offer.

# Where Quantum is Being Tested

## Quantum computing is being developed to solve specific types of problems, not to replace conventional computing.

Quantum processors use principles such as superposition and entanglement to perform certain calculations differently from CPUs and GPUs. Researchers are exploring their potential in areas such as complex simulations and problems involving large numbers of possible combinations. However, the practical benefits are still uncertain and vary by application.

Other fields are often discussed alongside quantum computing. Quantum communication uses quantum properties to transmit information and, for example, distribute encryption keys. Post-quantum cryptography, by contrast, develops encryption methods designed to withstand attacks from future quantum computers; it does not require quantum technology itself. These fields address different challenges and rely on different underlying mechanisms. Their maturity and evidence of practical advantage also vary considerably.

- **Quantum sensing** uses quantum properties to make highly precise measurements of physical phenomena. Established applications include atomic clocks and quantum magnetometers, while newer systems are being developed for navigation, geological surveying, materials research, mineral exploration, and healthcare. These applications have a different trajectory from large-scale quantum computing because they do not require fault-tolerant quantum processors.

- **Cryptography** requires preparation before quantum computers become capable of breaking current public-key encryption. A sufficiently capable quantum computer could compromise widely used public-key cryptographic schemes, creating a need to migrate systems and data to post-quantum cryptography, particularly where information needs to remain secure for many years.

- **Simulation** can, in principle, model other quantum and molecular systems more naturally than classical computers. This is driving research in chemistry, materials science, and drug discovery, with work focused on determining where quantum processors can produce useful results that are difficult or costly to obtain classically.

- **Optimisation** is being tested on problems such as logistics, scheduling, portfolio construction, and network planning, where there can be large numbers of possible combinations. Results remain mixed, and broad practical advantage over the best classical methods has not been established.

- **Quantum communications and networking** are being developed to transmit quantum information between distant systems and eventually connect quantum computers and sensors. Potential applications include secure communications and distributed sensing. The technology is still under development, with research focused on components such as quantum memories, repeaters, transducers, detectors, and network protocols.

**AI** applications in machine learning, optimisation, and other computationally intensive workloads are being explored using quantum computing. This remains an earlier-stage area of research, with limited evidence that quantum approaches can outperform established classical AI methods. Current work is focused on identifying specific problems where quantum processing could eventually provide an advantage.

SPOTLIGHT

# CRYPTOGRAPHIC RISK

A sufficiently capable fault-tolerant quantum computer could break widely used public-key cryptography. That includes RSA, Diffie-Hellman, and elliptic-curve cryptography, which are used for key exchange and digital signatures. The timing is uncertain, but organisations cannot wait for the technology to arrive before addressing the risk because replacing cryptography across large technology environments takes time.

## The threat to public-key cryptography

RSA, Diffie-Hellman, and elliptic-curve cryptography underpin key exchange and digital signatures across applications, networks, identity systems, and digital transactions. Shor's algorithm provides a known method for using a sufficiently capable quantum computer to attack the mathematical problems behind these schemes. Many blockchain systems also rely on elliptic-curve digital signatures.

## The risk starts before the attack is possible

Encrypted information can be captured and stored today for decryption later, known as “harvest now, decrypt later”. This is particularly relevant to data that needs to remain confidential for many years, including government and defence information, financial records, health data, legal records, and intellectual property. The European Commission has said such attacks are already likely occurring.

## The standards are available

NIST finalised three post-quantum cryptography standards in August 2024: FIPS 203 (ML-KEM) for key establishment and FIPS 204 (ML-DSA) and FIPS 205 (SLH-DSA) for digital signatures. In 2025, NIST selected HQC as an additional key-encapsulation algorithm to provide a backup to ML-KEM. NIST recommends that organisations begin migration now.

## Migration requires an inventory of existing cryptography

Public-key cryptography is embedded in applications, certificates, devices, identity systems, network protocols, software libraries, and third-party services. Organisations therefore need to identify where vulnerable algorithms are used, determine which systems and data require priority, and plan their replacement. NIST's migration guidance recommends this inventory and planning process. The UK's National Cyber Security Centre has set 2028 for completing discovery and initial migration planning, 2031 for high-priority migration, and 2035 for completing migration.

Quantum computing may still be years away from affecting most enterprise workloads. The security implications of the technology require action earlier because cryptographic migration itself takes years.

## Quantum Applications Across Industries

Quantum applications are being explored for specific computational and measurement problems. Organisations are testing the technology in areas including molecular simulation, optimisation, materials modelling, engineering simulation, financial calculations, and network operations.



### Healthcare and Life Sciences

**Quantum computing is being explored for molecular simulation, including problems relevant to drug discovery and protein-ligand interactions.**

Cleveland Clinic, RIKEN, and IBM have used quantum processors alongside conventional supercomputers to simulate protein-ligand systems containing up to 12,635 atoms. The hybrid approach uses quantum processors for part of the calculation, with classical systems processing the results. The researchers reported a 210-fold improvement in accuracy over their previous approach.



### Defence and Logistics

**Quantum optimisation is being tested for mission planning and logistics, where decisions can involve multiple resources, routes, timelines, and other operational constraints.**

Singapore's Digital and Intelligence Service and Defence Science and Technology Agency are evaluating quantum optimisation for a representative mission-planning problem, including logistics. The programme also gives DIS and DSTA engineers experience working with quantum computing resources, algorithms, and software.

The work combines evaluation of a specific planning problem with development of technical capability to assess quantum approaches as the technology develops.



### Materials and Energy

**Quantum computing is being tested in materials science to model the behaviour of interacting electrons, including in materials relevant to energy applications.**

Q-CTRL used 120 qubits to simulate 60 interacting electrons and reported reducing computation time from more than 100 hours to two minutes against the classical software benchmark used in its test. The company described the result as evidence of practical quantum advantage.

The comparison has also highlighted the importance of the classical baseline. A subsequent specialised implementation challenged the original comparison, illustrating that reported quantum performance depends on the classical method used as the benchmark.

Energy companies are exploring different applications. EDF has tested quantum approaches for forecasting energy demand and renewable-power output, where supply, demand, weather, and network variables need to be considered together.



## Aerospace

**Aerospace companies are testing quantum computing across optimisation, materials design, and engineering simulation.**

Airbus has explored aircraft-loading optimisation, Boeing has investigated composite-material design, and Rolls-Royce has explored computational fluid dynamics for jet engines. The applications cover different types of computational problem, from optimisation and materials modelling to physical simulation.

These remain exploratory applications. The work shows how quantum approaches are being evaluated against specific engineering problems rather than only against general-purpose benchmarks.



## Financial Services

**Financial services has potential applications in optimisation, simulation, and other computationally intensive workloads.**

Potential applications include portfolio construction, derivatives pricing, liquidity management, risk analysis, fraud detection, and trading. Documented use cases include portfolio optimisation at Goldman Sachs and arbitrage optimisation at Hitachi.

The applications remain at different stages of development, and identifying a problem that can be formulated for a quantum algorithm does not establish an advantage over classical methods at commercially relevant scale.



## Telecommunications

**Quantum computing is being explored for network operations, including communication-service fault diagnosis.**

SoftBank has explored quantum machine learning approaches for fault diagnosis, applying quantum methods to network-operations automation.

The work represents an application of quantum computing to operational network data rather than the optimisation and simulation problems more commonly associated with quantum computing research. It remains exploratory, with the performance of quantum approaches needing to be assessed against established machine learning methods.



# Asia Pacific Quantum Readiness: A Regional View

**Asia Pacific accounts for a growing, though still modest, share of global quantum activity. Much of the investment remains concentrated in academic research and government programs, with corporate investment less developed. Progress also varies significantly across the region.**

Countries are taking different approaches, shaped by their technical strengths and domestic priorities. Some are developing processors, components and software for the wider quantum industry; others are focusing on research, talent and potential applications. Accessing overseas systems and cloud-based quantum services is another route to building local expertise and exploring use cases, without developing a domestic hardware industry. Public funding figures provide useful context, but differences in scope, duration and what the budgets cover make direct comparisons difficult.

Based on public investment, demonstrated technical capabilities, access to quantum infrastructure and industry participation, the assessment below also considers how far countries have moved beyond announced plans to build and deploy working systems.

## Quantum Development Across Asia Pacific: Different Levels of Readiness

**Tier 1: Leaders** (Strategy, hardware, infrastructure and industry all in place)

### Japan

HARDWARE COMPUTE

**Built:** 256-qubit computer; ABCI-Q

**Next:** Industrial applications

### Korea

SUPPLY CHAIN COMPUTE

**Built:** IonQ Tempo; K-Quantum Foundry

**Next:** Homegrown 100-qubit chip by 2029

### Singapore

RESEARCH SOFTWARE COMPUTE

**Built:** CQT; NQCH; USD222M national strategy

**Next:** Quantinuum Helios deployment

### Australia

HARDWARE

**Built:** SQC 11-qubit processor; Diraq 8-qubit array; PsiQuantum lab

**Next:** Fault-tolerant photonic computer

### China

HARDWARE COMPUTE

**Built:** Zuchongzhi 3.2; Wukong-180; Tianyan cloud

**Next:** Fault-tolerant general-purpose systems

**Fast scaling challengers** (Building quickly, with partners filling gaps)

### India

HARDWARE SOFTWARE COMPUTE

**Built:** National Quantum Mission; QpiAI Indus and Kaveri

**Next:** IBM System Two in Amaravati

### Taiwan

SUPPLY CHAIN HARDWARE

**Built:** Academia Sinica 20-qubit computer; Rigetti–Quanta partnership

**Next:** Quantum chip fabrication

**Strong research, fragmented coordination** (Specialist depth, no unified build-out)

### New Zealand

RESEARCH SUPPLY CHAIN

**Built:** Dodd-Walls Centre; Quantum Technologies Aotearoa

**Next:** Quantum supply-chain investment

### Hong Kong

RESEARCH COMPUTE

**Built:** CityU–Origin Quantum partnership; HKUST collaborations

**Next:** Local Wukong computer

**Emerging builders** (Early capability, led by partnerships)

### Malaysia

RESEARCH

**Built:** MIMOS Quantum Intelligence Centre; IBM partnership

**Next:** National centre development

### Thailand

RESEARCH COMPUTE

**Built:** Siam Quantum Square; USTC partnership

**Next:** Trapped-ion computer by 2027

### Indonesia

RESEARCH

**Built:** BRIN Quantum Physics Centre; university partnerships

**Next:** Broader research capability

*Built = delivered | Next = announced or planned*

*Tags show where each market plays, not a score.*

# LEADERS

## Japan

A sustained national strategy focused on industrialisation. Three linked frameworks – the Quantum Technology and Innovation Strategy (2020), Vision of Quantum Future Society (2022) and Strategy of Quantum Future Industry Development (2023) – guide Japan's progression from research towards commercialisation and industrial adoption.

Credible domestic quantum hardware. RIKEN and Fujitsu unveiled a 256-qubit superconducting quantum computer in April 2025, demonstrating domestic system development supported by strengths in semiconductors, materials and precision engineering.

Operational infrastructure connecting research with industry. AIST's G-QuAT operates ABCI-Q, combining GPU supercomputing with quantum computing platforms for application development. Fujitsu superconducting and QuEra neutral-atom systems became available to external users through initiatives such as the Fujitsu Quantum Simulator Challenge.

## Korea

A national initiative focused on domestic quantum industrialisation. South Korea's August 2026 Seven SEED initiative targets a homegrown 100-qubit processing unit capable of error correction by 2029 and global quantum-chip manufacturing leadership within a decade.

An industry-led push across the computing stack. A national competition will support domestic companies developing quantum chips, controls and software. The planned K-Quantum Foundry leverages commercial partners like SkyWater Quantum Solutions to establish quantum-chip mass production.

Advanced computing infrastructure through IonQ and KISTI. The Korea Institute of Science and Technology Information has agreed to acquire IonQ's 100-qubit Tempo trapped-ion computer for integration with the HANGANG national supercomputer, supporting hybrid quantum-classical research and applications.

## Singapore

An established research base backed by national investment. Singapore's Centre for Quantum Technologies (CQT), founded in 2007, provides sustained scientific expertise. The 2024 National Quantum Strategy committed nearly USD 222M over five years across quantum technologies, supporting research, engineering, talent and commercialisation.

Computing infrastructure and software supported by international partnerships. The National Quantum Computing Hub (NQCH) connects quantum computing with national supercomputing resources at NSCC Singapore. Quantinuum opened a Singapore R&D centre ahead of a planned Helios deployment, while Horizon Quantum Computing contributes its software infrastructure and testbed integrating hardware from international suppliers.

### Australia

Advanced Australian-led capabilities in silicon quantum hardware. Silicon Quantum Computing demonstrated an 11-qubit atom processor in December 2025, connecting two groups of qubits with high-fidelity quantum operations. Diraq and Belgium's imec demonstrated coherent operation of an eight-qubit silicon array fabricated using a 300mm CMOS-compatible process in July 2026.

A major investment in a planned quantum computing facility. The Australian and Queensland governments committed USD 1B in equity and loans to PsiQuantum to develop a fault-tolerant photonic quantum computer in Queensland. Its Test and Validation Lab at Griffith University was officially launched in May 2026 to support component and subsystem development.

### China

National strategy prioritising quantum computing development. China's 15th Five-Year Plan (2026-2030) identifies quantum technology as a priority future industry, explicitly calling for fault-tolerant general-purpose quantum computers and scalable special-purpose quantum computing systems.

Advanced processor development and quantum error correction. USTC's 105-qubit Zuchongzhi 3.0 demonstrated quantum computational advantage on a specialised sampling task. Its 107-qubit Zuchongzhi 3.2 subsequently demonstrated below-threshold error correction, an important advance towards reliable quantum computing.

Domestic quantum computers available through operational cloud services. Origin Quantum's 180-qubit Wukong-180 system, launched in May 2026, provides programmable hardware through Origin Quantum Cloud. China Telecom's Tianyan Quantum Cloud Platform also offers cloud access to domestic quantum hardware.

## FAST SCALING CHALLENGERS

### India

A national mission to build quantum computing capability. India's National Quantum Mission allocates ₹6,003.65 crore across quantum technologies through 2030-31, including development of 50-1,000 physical-qubit computers. IISc Bengaluru hosts its quantum computing hub.

Domestic development complemented by international systems. QpiAI develops processors, controls and software, launching its 25-qubit Indus system in April 2025 and announcing its 64-qubit Kaveri processor in November 2025. A planned IBM Quantum System Two at Amaravati, supported by TCS, would expand computing access and application development.

### Taiwan

Established electronics manufacturers entering the quantum supply chain. Quanta Computer invested USD 35M in Rigetti Computing in April 2025 alongside a superconducting quantum computing partnership. Kinpo is co-developing room-temperature control electronics with SEEQC, extending Taiwan's electronics expertise into quantum systems.

Domestic processor development backed by fabrication expertise. Academia Sinica unveiled a 20-qubit superconducting quantum computer in January 2026, accessible to local academic researchers. Its quantum-chip fabrication and computing test platforms support further hardware development and system integration.

## STRONG RESEARCH, FRAGMENTED COORDINATION

### New Zealand

Specialist research with an emerging supply-chain focus. The Dodd-Walls Centre leads Quantum Technologies Aotearoa, supported by up to USD 6.7M over five years across quantum technologies. NZIAT is assessing potential investment in specialised components, cryogenics and computing software for international quantum supply chains.

### Hong Kong

University-led development supported by mainland partnerships. City University of Hong Kong agreed in April 2026 to establish an Advanced Computing Centre with Origin Quantum, including a planned local Wukong quantum computer. HKUST's partnerships with China Telecom and SpinQ support computing applications and error-correction research.

## EMERGING BUILDERS

### Malaysia

Early capability-building through MIMOS and international partnerships. Malaysia launched the MIMOS Quantum Intelligence Centre in 2025 to support applied quantum research. A July 2026 agreement with IBM explores a National Quantum and Artificial Intelligence Centre of Excellence focused on research, skills and industry collaboration.

### Thailand

University-led capability-building through international partnerships. Chulalongkorn University's Siam Quantum Square ($SQ^2$), launched in January 2026, connects research and industry partners including IBM. A trapped-ion computer planned for installation in 2027 through a partnership with USTC and Hefei Unitary Quantum Technology would provide local hardware for research and training.

### Indonesia

An early research base centred on public institutions. BRIN's Research Center for Quantum Physics, established in 2022, includes quantum computation, simulation and device research groups. Collaboration with Institut Teknologi Bandung and Telkom University supports research.

SPOTLIGHT

# QUANTUM GEOPOLITICS

Quantum technology is becoming part of national technology policy. Governments are funding research and domestic capability while some are also applying export controls to quantum hardware, software, components, and related technologies. The policy focus reflects the potential use of quantum technology in areas including defence, cryptography, sensing, and advanced computing.

## Export controls are beginning to cover quantum technology

The US introduced controls on quantum computers and related technologies in September 2024, covering areas including components, software, and cryogenic systems. Several countries have also introduced or considered controls on advanced technologies, including quantum technologies. The measures differ in scope, but they point to growing government scrutiny of access to capabilities with potential security applications.

## Cloud access adds another layer

Quantum processors are increasingly available through cloud platforms, so access does not always require physical possession of the hardware. This raises a policy question over whether controls should also apply to remote access to restricted systems. The US considered this issue in the Remote Access Security Act, which proposed extending export-control authority to certain remote access through networks and cloud services. The bill passed the House in 2024 but did not become law.

## Countries are also building domestic capability

National quantum programs across Asia Pacific, North America, and Europe cover research, hardware, software, infrastructure, skills, and commercial development. Some programs also emphasise domestic supply chains and reduced dependence on foreign technology. The balance between international collaboration and domestic capability varies by country.

## The policy environment is becoming more complex

Quantum technology is developing through international research and commercial partnerships, while governments are also deciding which capabilities should remain accessible, where critical technologies should be developed, and how much dependence on foreign suppliers is acceptable. Export controls, national funding, research policy, and supply-chain policy are becoming part of the same conversation.

Quantum computing is still developing, but the policy surrounding it is developing at the same time. The result is a global technology market operating within different national rules on research, trade, access, and security.

# The Future Outlook

**Quantum computing is likely to develop through several stages rather than arrive as a single breakthrough.**

The exact timing is uncertain, but current research programs and industry roadmaps provide useful reference points. DARPA is assessing whether any quantum architecture can reach utility-scale operation (meaning its computational value exceeds its cost) by 2033, while companies like Google are pursuing their own paths towards fault-tolerant systems. These dates are targets and assessment points, not established industry forecasts.

## 1. 2026-2029: EXPERIMENTATION & EARLY QUANTUM ADVANTAGE

Quantum processors are already available through cloud platforms, and organisations are testing specific problems in areas such as simulation, optimisation, materials, chemistry, and finance.

The next few years will provide more evidence about where quantum systems can produce useful results against strong classical alternatives. Hardware development will focus on improving error rates, logical qubits, circuit performance, and the ability to integrate quantum processors with conventional high-performance computing.

Post-quantum cryptography follows a separate timeline. The standards are already available, and migration can begin without waiting for further quantum hardware progress.

## 2. 2029-2033: FAULT-TOLERANT SYSTEMS & UTILITY-SCALE COMPUTING

This is an indicative window for the emergence of increasingly capable fault-tolerant systems. Quantinuum has targeted fully fault-tolerant universal quantum computing by 2030, with its Apollo system scheduled for 2029, while DARPA is testing whether a utility-scale quantum computer can be built by 2033.

If these milestones are achieved, quantum computing could move into a wider set of useful workloads. Hybrid systems are likely to remain important, with quantum processors handling specific calculations alongside classical computing.

The applications that become practical will depend on the performance achieved and the strength of competing classical methods. Materials modelling, molecular simulation, optimisation, and financial calculations are among the areas already being tested, but the scale of any commercial advantage remains uncertain.

## 3. 2033 & BEYOND: SCALING & WIDER APPLICATION

Beyond the first utility-scale systems, the focus will be on whether quantum computing can scale economically and deliver advantages across a broader range of problems. This could expand its use in simulation, optimisation, cryptography, and other computationally intensive applications.

The timing and extent of this expansion cannot yet be established. DARPA frames utility-scale quantum computing as something to be verified rather than assumed and is using its program to determine whether it can be achieved. Its program leadership has said it now seems likely that someone will succeed by 2033, though it remains unclear which team or teams will.

### THE TIMELINE IS INDICATIVE

A slower trajectory would leave quantum computing focused on experimentation and selected applications for longer. Faster progress in error correction and hardware could bring useful fault-tolerant systems into operation earlier.

The milestones to watch are measurable: improvements in logical-qubit reliability, demonstrated advantage against strong classical benchmarks, fault-tolerant operation, integration with high-performance computing, and evidence that quantum performance translates into useful results at practical scale.

Cryptographic migration should remain on its own timetable. Its urgency depends on the time required to identify and replace vulnerable systems, not on knowing exactly when a cryptographically relevant quantum computer will exist.

# Implications for Business and Government Leaders

**Quantum computing is still developing, so the priorities for organisations are different from those for governments.**

Organisations need to determine where the technology is relevant and prepare for the security implications. Governments are already investing in the research, infrastructure, skills, standards, and industrial capabilities needed to develop national quantum capacity. The next phase is about connecting these efforts and deciding where to focus them.

## For Organisations

- **Identify problems worth testing**
  Focus on specific computational problems where quantum methods could plausibly offer an advantage, rather than treating quantum computing as a general-purpose technology. Use existing research, cloud platforms, and external providers to test those problems against strong classical alternatives.
- **Build enough expertise to evaluate the technology**
  Organisations do not need large quantum teams at this stage. They do need people who can assess use cases, understand the technology's limitations, and work with quantum providers, researchers, and internal technology teams.
- **Plan for hybrid computing**
  Quantum systems are likely to work alongside conventional computing for some time. Evaluate how quantum workloads could connect to existing HPC, cloud, data, and software environments before making significant infrastructure commitments.
- **Start cryptographic migration**
  Inventory where vulnerable public-key cryptography is used across applications, infrastructure, devices, certificates, and third-party services. NIST already recommends beginning migration to its post-quantum standards rather than waiting for a cryptographically relevant quantum computer.
- **Track technology and supplier dependencies**
  Quantum hardware, cloud access, software, standards, and specialised components are developing through a relatively small number of providers and national programmes. Organisations should understand which dependencies matter to their potential use cases and monitor changes in technology, regulation, and access.

## For Governments

- **Strengthen national quantum capability**
  Fund research, testbeds, computing access, networking, sensing, and shared infrastructure where scale and cost make private investment difficult.
- **Build the talent base**
  Expand doctoral research, technical training, engineering, software, and applied skills needed to develop and use quantum technologies.
- **Connect research to applications**
  Give researchers and businesses access to quantum systems and funding to test defined use cases through challenge programs, procurement, and shared facilities.
- **Make PQC migration a national program**
  Inventory vulnerable cryptography across government systems, set migration priorities, update procurement requirements, and coordinate with critical infrastructure and industry.
- **Strengthen critical supply chains**
  Identify the components, materials, hardware, software, and infrastructure that are strategically important, and assess where dependence on foreign suppliers creates a risk.
- **Coordinate technology and security policy**
  Keep export controls, standards, procurement rules, research policy, cybersecurity requirements, and international partnerships aligned as quantum capabilities develop. Avoid committing national resources to a single hardware approach before the technology has established which architectures and applications will scale.

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