**IBM Technology Atlas**

# Quantum Roadmap

**The future of computing is quantum-centric.**

Realized
In progress

| | 2026 | 2028 | 2029+ |
|---|---|---|---|
| The journey | *Enable the first examples of quantum advantage using a quantum computer with HPC.* | *Diversify quantum advantage and entangle fault-tolerant modules.* | *Deliver large-scale fault-tolerant quantum computers.* |

**What are we doing and how we are doing it**

**Implications for:**

- Automation
- Data
- Security
- Systems

## 2026

(Systems) We will have the first examples of quantum advantage using a quantum computer with an HPC. This integration of heterogeneous systems will lead to the development of a standard to allow seamless integration with classical systems across different quantum hardware vendors. Users will be able to run workloads that involve quantum and classical resources by writing quantum and classical code and deploying it in an integrated system. In 2026 and beyond, we will introduce new profiling tools to help users monitor, verify, and debug workloads across quantum and classical resources.

IBM Quantum Nighthawk is our platform for exploring and scaling quantum advantage ahead of large-scale fault-tolerant quantum computing. It uses a square lattice, connecting each qubit to up to four neighbors. Paired with techniques that reduce errors, Nighthawk is expected to run circuits with 7,500 gates in 2026 in with up to three 120-qubit modules (360 qubits), 10,000 gates in 2027, and 15,000 gates in 2028. As we improve and scale Nighthawk, we expect major progress toward quantum advantage.

IBM Quantum Loon debuted in 2025 with a new chip architecture that leverages c-couplers to link qubits across the chip, beyond nearest neighbors. It enables up to six degrees of connectivity between qubits. This improved connectivity is needed to implement IBM's scalable error-correcting code. This advancement strengthens our confidence in achieving large-scale, fault-tolerant quantum computing by 2029. In 2026, we will prototype our error correction decoder, which will enable real-time error correction—a key capability for scalable, fault-tolerant quantum computing.

We will continue to deliver improvements to dynamic circuits, error mitigation, and speed in the coming years to extend the capabilities of our available quantum systems.

We will introduce utility mapping tools that support the exploration and design of new algorithms by mapping problems to circuits that scale prior to fault tolerance. We will also work with partners to create a use case benchmarking tool, enabling others to explore which of their applications are ripe for near-term quantum value.

(Automation) Patterns will begin to appear in workflows within the quantum advantage regime, providing the opportunity to start applying AI-driven automation to combine quantum and classical resources and set up and manage the components and configurations of these workflows. AI will also start driving improvements in quantum system setup and enhance the developer experience by enabling more efficient code development.

To prepare for the future, Kookaburra will demonstrate a single module out of Starling consisting of a logical processing unit and quantum memory.

(Data) (Security) Meanwhile, as the technology progresses toward large-scale, fault-tolerant quantum computing, the need for quantum-safe cryptographic protocols to protect data in flight and digital signatures intensifies. Cryptographically-relevant quantum computers may not arrive for some years but completing an inventory of cryptography in an organization, performing a risk assessment, migrating vulnerable cryptography, and implementing a crypto-agility framework will take several years. This, combined with harvest now, decrypt later threats, means enterprises needing strong data protection should already be evaluating and implementing an action plan.

## 2028

In 2027, we will diversify quantum advantage and entangle fault-tolerant modules. The performance of our Nighthawk processor will improve to allow circuits with up to 10,000 gates on up to 1080 qubits in 2027, scaling to up to 15,000 gates in 2028.

We will introduce computation libraries. These provide mathematical subroutines for applications that integrate with popular existing computational libraries to support collaboration, integration, and help users more efficiently build and orchestrate workflows across classical and quantum compute resources.

We will introduce workflow accelerators that deliver optimized quantum-classical execution pipelines for efficiently running similar tasks. This will save developers valuable compute time.

In 2028, we will prototype a complete instruction set architecture including magic state distillation for fault-tolerant quantum computing in our Starling proof-of-concept, to be released in 2029.

To prepare for the future, in 2027 the Cockatoo processor will demonstrate entanglement of two modules using a universal adapter. In 2028, we will demonstrate multiple modules and magic state distillation.

(Automation) Fueled by the momentum of quantum advantage, we expect to see agentic tools emerge that efficiently map problems to quantum workflows to help domain experts and industry practitioners engage more easily and effectively with quantum computing.

## 2029+

The first fault-tolerant quantum computer, Starling, will be available to clients in 2029. It will be a modular, error-corrected quantum-centric supercomputer with 200 qubits capable of running 100 million gates. It will enable the development of more sophisticated circuit libraries. We will continue to scale electronics, infrastructure, and software to reduce footprint, cost, and energy usage.

We expect to provide libraries that offer an expanded, generalized set of circuits ideal for execution on fault-tolerant processors.

By 2033+, we will scale fault-tolerant quantum computers to deliver a system, called Blue Jay, capable of running circuits of 1 billion gates on up to 2000 qubits with a power consumption of 2 megawatts. This will require a new control electronics and cryogenics infrastructure.

Extensions of the computation and circuit libraries will scale and diversify quantum computing + HPC workflows across industries. For the future, we will scale beyond Blue Jay with the development of distributed quantum computing, bringing together the fields of quantum communication and quantum computation. These large-scale fault-tolerant quantum computers will unlock a new era of algorithmic complexity and application discovery. Developers will not need to change how they write quantum programs in this era. They will simply notice that they can run longer workloads.

(Systems) The vast amount of data that these systems will process will introduce significant complexities. Mechanisms will be required to efficiently compress and stream data across different computational components. In this context, AI can play a critical role by optimizing and compressing data transfers between quantum and classical resources, ensuring seamless and efficient movement of information.

(Data) In scenarios where multi-agent systems manage entire workflows and automatically adapt considering both the problem and available resources, quantum systems will leverage this adaptability to align with the application's top layer. In heterogeneous computing environments, this will become a key differentiator, evolving agentic components into self-sufficient operational entities that support discovery, integration, and governance.