2025
Development & Innovation Roadmap

IBM **Quantum**

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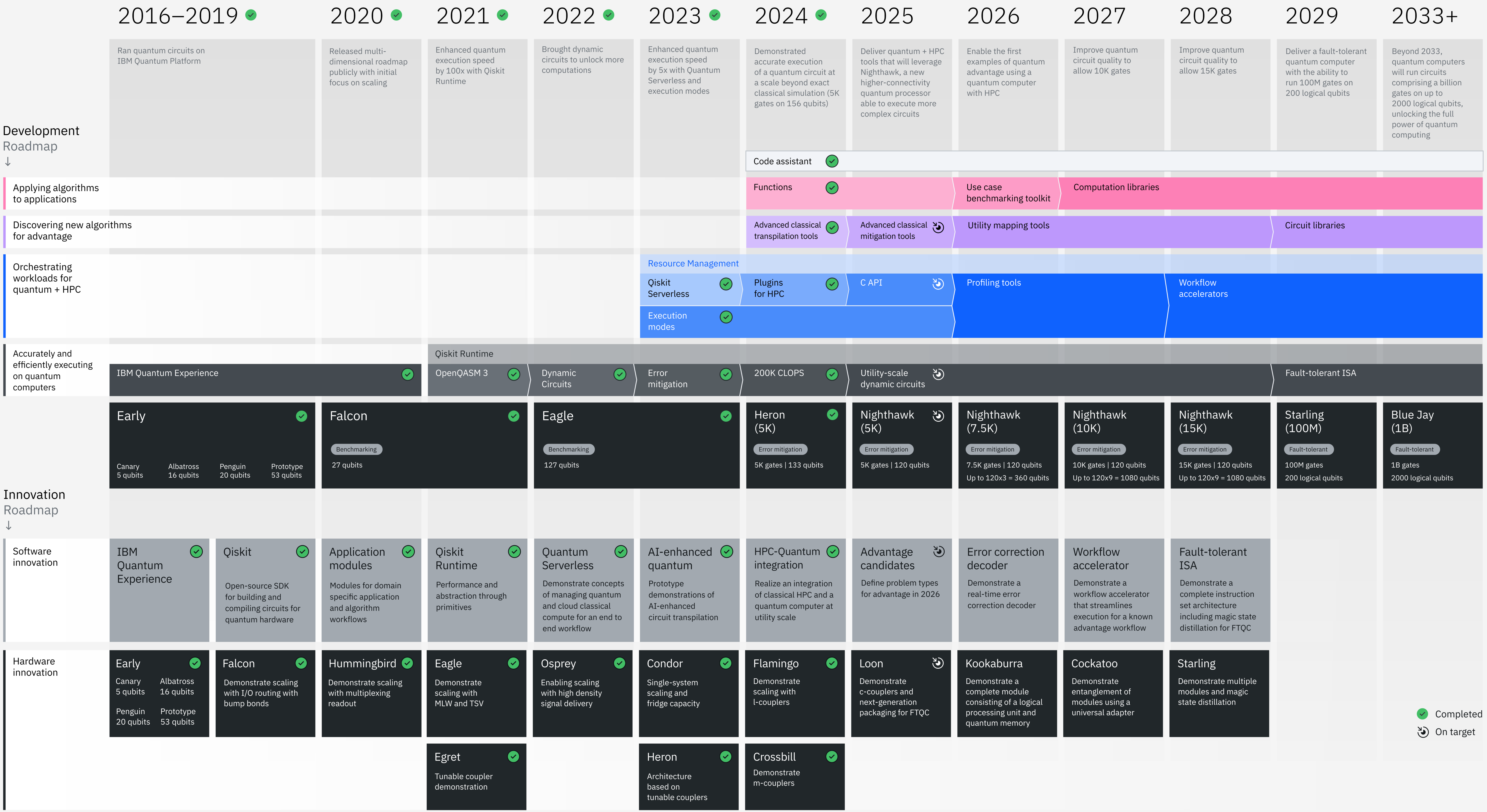

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2033+
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Enhanced quantum execution speed by 5x with Quantum Serverless and execution modes
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Deliver quantum + HPC tools that will leverage Nighthawk, a new higher-connectivity quantum processor able to execute more complex circuits
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Beyond 2033, quantum computers will run circuits comprising a billion gates on up to 2000 logical qubits, unlocking the full power of quantum computing
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Advanced classical mitigation tools
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C API
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Workflow accelerators
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Qiskit Runtime
IBM Quantum Experience
OpenQASM 3
Dynamic Circuits
Error mitigation
200K CLOPS
Utility-scale dynamic circuits
Fault-tolerant ISA
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Prototype 53 qubits
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100M gates
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Blue Jay (1B)
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Demonstrate scaling with l-couplers
Loon
Demonstrate c-couplers and next-generation packaging for FTQC
Kookaburra
Demonstrate a complete module consisting of a logical processing unit and quantum memory
Cockatoo
Demonstrate entanglement of modules using a universal adapter
Starling
Demonstrate multiple modules and magic state distillation
Egret
Tunable coupler demonstration
Heron
Architecture based on tunable couplers
Crossbill
Demonstrate m-couplers
Completed
On target

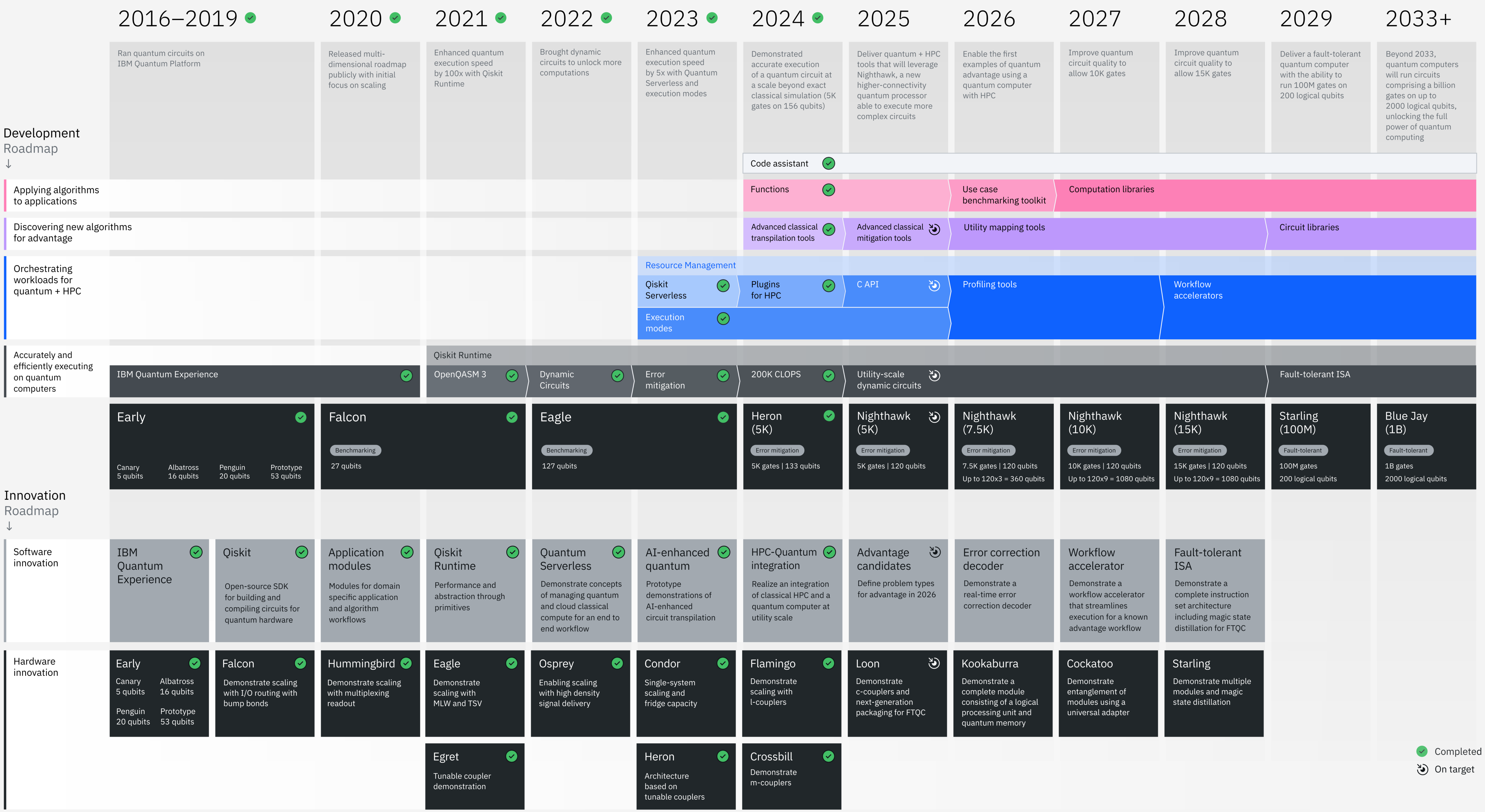
2025 Roadmap

IBM **Quantum**

In our 2023 roadmap, we committed to developing IBM Quantum Starling–the first large-scale, fault tolerant quantum computer–by 2029.

Our roadmap now reflects two more years of progress toward that milestone. We have introduced new hardware focused on increased qubit connectivity and restructured our quantum software development plans around four key objectives.

These updates will be detailed in the following slides.



As part of our commitment to transparent quantum development, our roadmap is split into two parts:

Development Roadmap

Tracks the release of production hardware, software, and services delivered to users.

Innovation Roadmap

Charts the scientific breakthroughs and internal releases that underpin development milestones. Some items will remain internal proofs-of-concept, while others may evolve into future external releases.

2025 Development Roadmap→

2025 Development Roadmap: Hardware

IBM **Quantum**

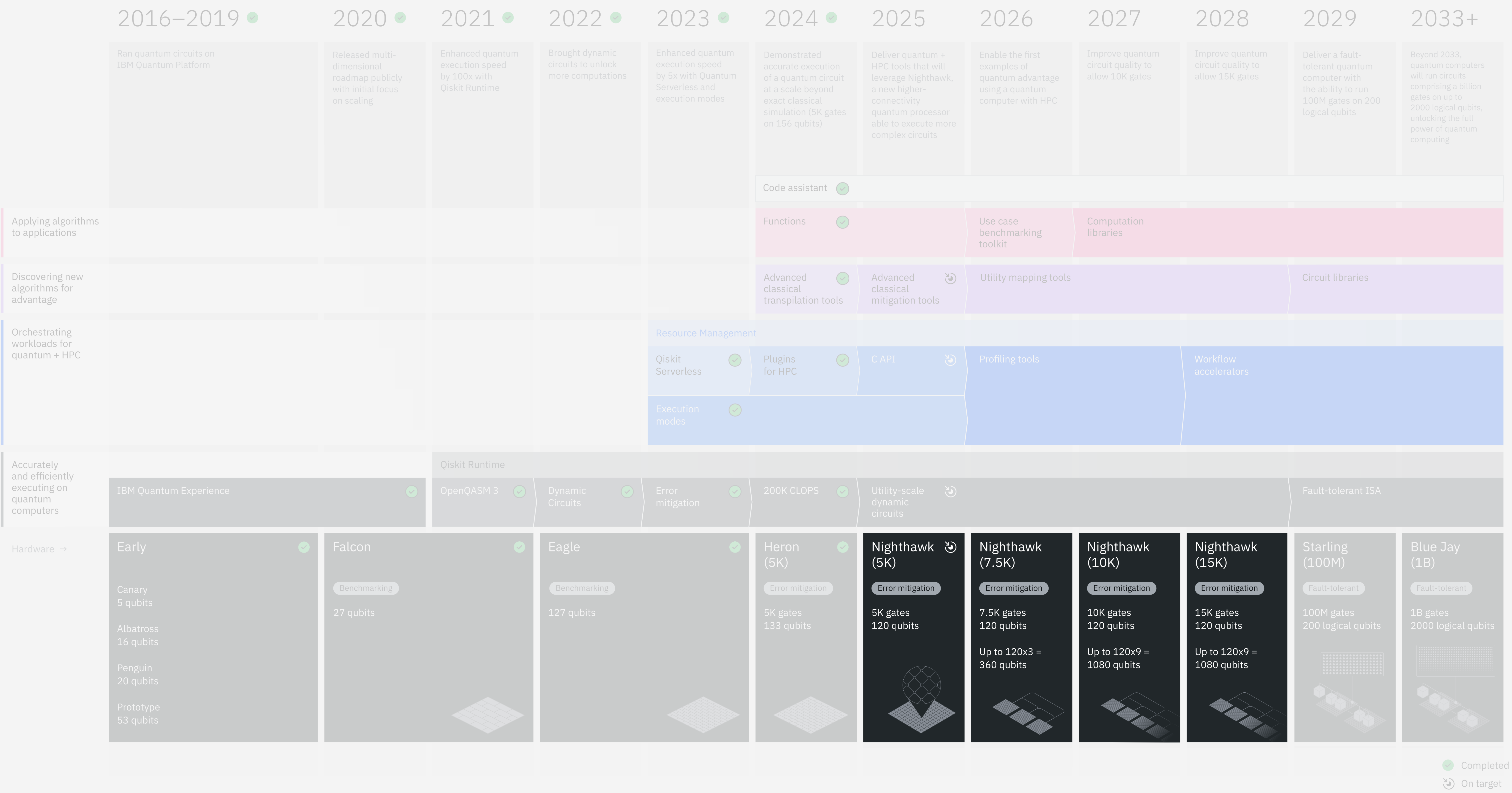
IBM Quantum Nighthawk is our platform for exploring and scaling quantum advantage ahead of large-scale fault-tolerant quantum computing.

Previously, our quantum processors used a “heavy-hex” lattice, with each qubit connected to up to three neighbors. Nighthawk moves us to a square lattice, connecting each qubit to up to four neighbors.

This square lattice supports more efficient circuits, with fewer gates required for information routing. As a result, users can run more complex algorithms at the same gate scale.

Paired with techniques that reduce errors, Nighthawk is expected to run circuits with 5,000 gates in 2025, 7,500 gates in 2026, 10,000 gates in 2027, and 15,000 gates in 2028.

As we improve and scale Nighthawk, we expect our team and partners to make major progress toward quantum advantage.



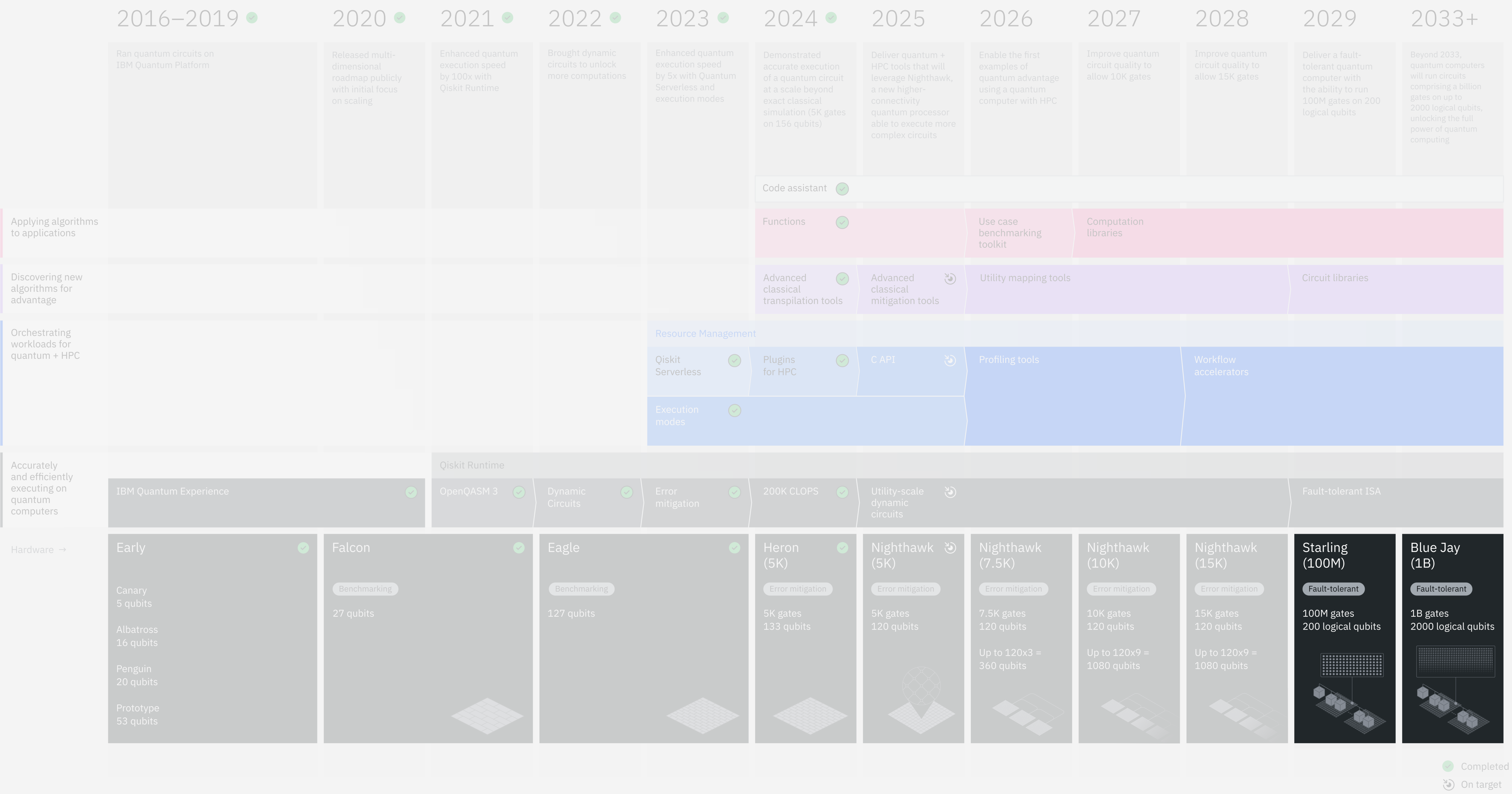
2025 Development Roadmap: Hardware

IBM **Quantum**

At the same time, we are driving toward **IBM Quantum Starling**—a system capable of running circuits with 100 million gates on 200 logical qubits—and aim to debut it by 2029.

In 2033, we will debut **IBM Quantum Blue Jay**, a system capable of running circuits with a billion gates on 2,000 logical qubits. 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.



2025 Development Roadmap: Software, orchestration, and execution

IBM **Quantum**

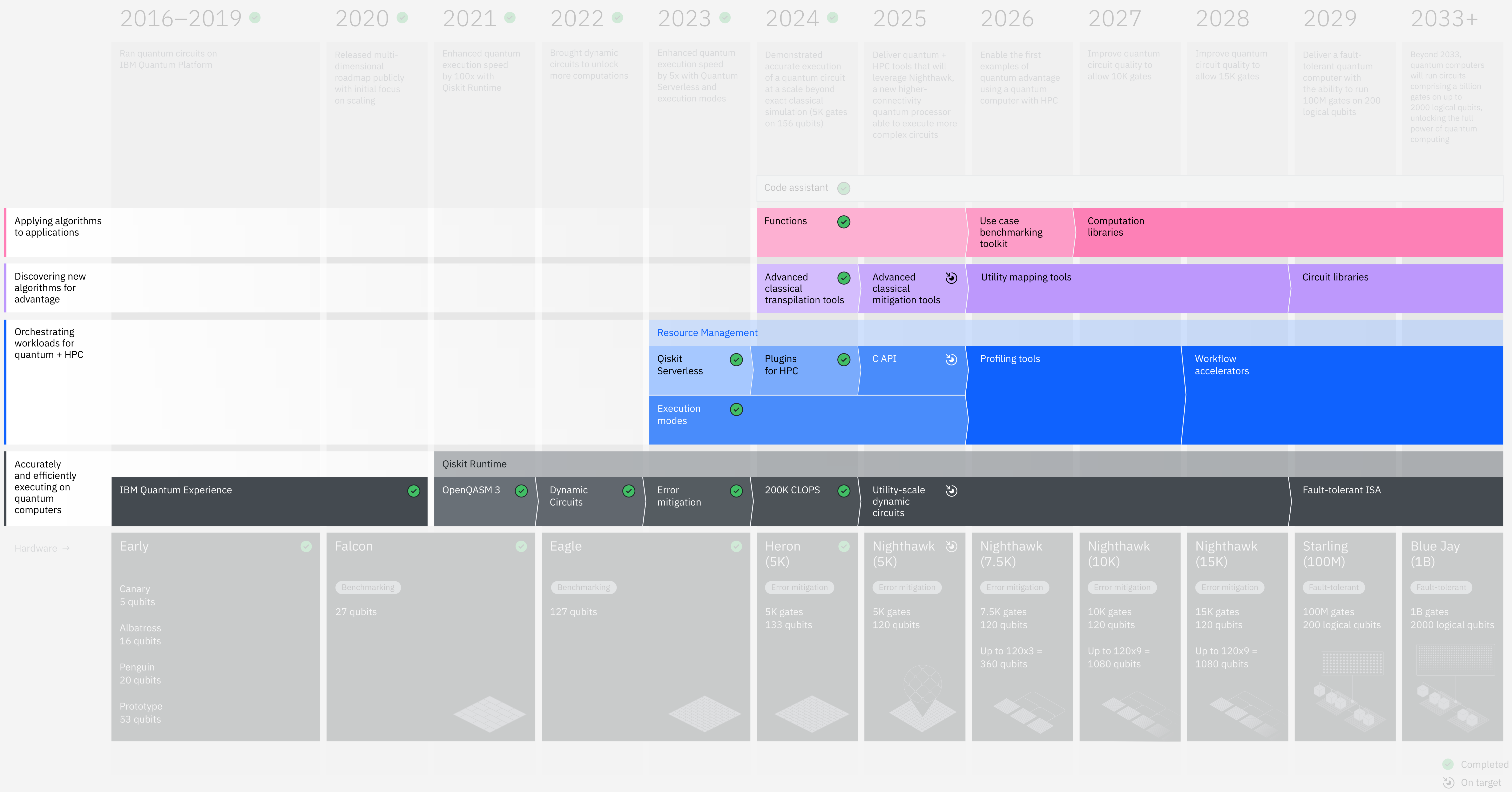
Useful quantum computing requires high-performance software. Our updated roadmap outlines four broad software objectives:

Apply algorithms to applications. These advances will let users adapt existing algorithms to domain-specific use cases.

Discover new algorithms for advantage. To move quickly to advantage, we must continue to improve and discover new algorithms. These advances provide a roadmap for tools that will enable new algorithm discovery.

Orchestrate workloads for quantum & high-performance computing (HPC). No algorithms are purely quantum, and we can more efficiently scale algorithms when we leverage quantum and classical resources together. So we are developing tools to better integrate and use quantum and classical resources.

Execute accurately and efficiently. We will continue to deliver high-performance software that runs circuits accurately on our evolving quantum hardware.

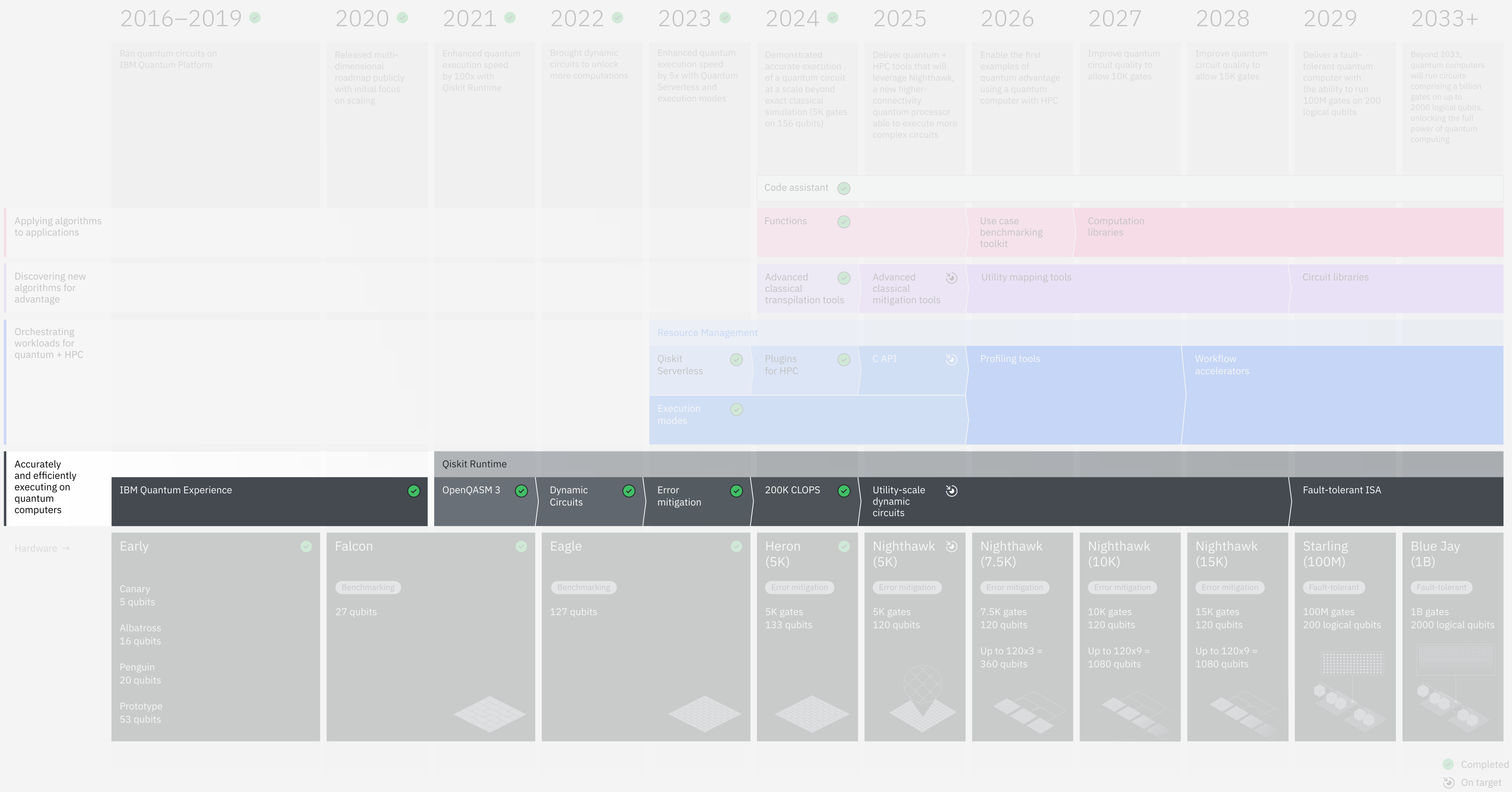


IBM **Quantum**

2025 Development Roadmap: Execute accurately and efficiently

In 2025, we aim to introduce utility-scale dynamic circuits, extending the horizon of what can be accomplished on our existing quantum computers. This will allow us to run even larger and more complex circuits, which are required to realize useful quantum computing.

The work continues, even after a box is checked off on our roadmap. We will continue to deliver improvements to dynamic circuits, error mitigation, and speed in the coming years, further extending the capabilities available to our users.



2025 Development Roadmap: Orchestrating workloads for quantum & HPC

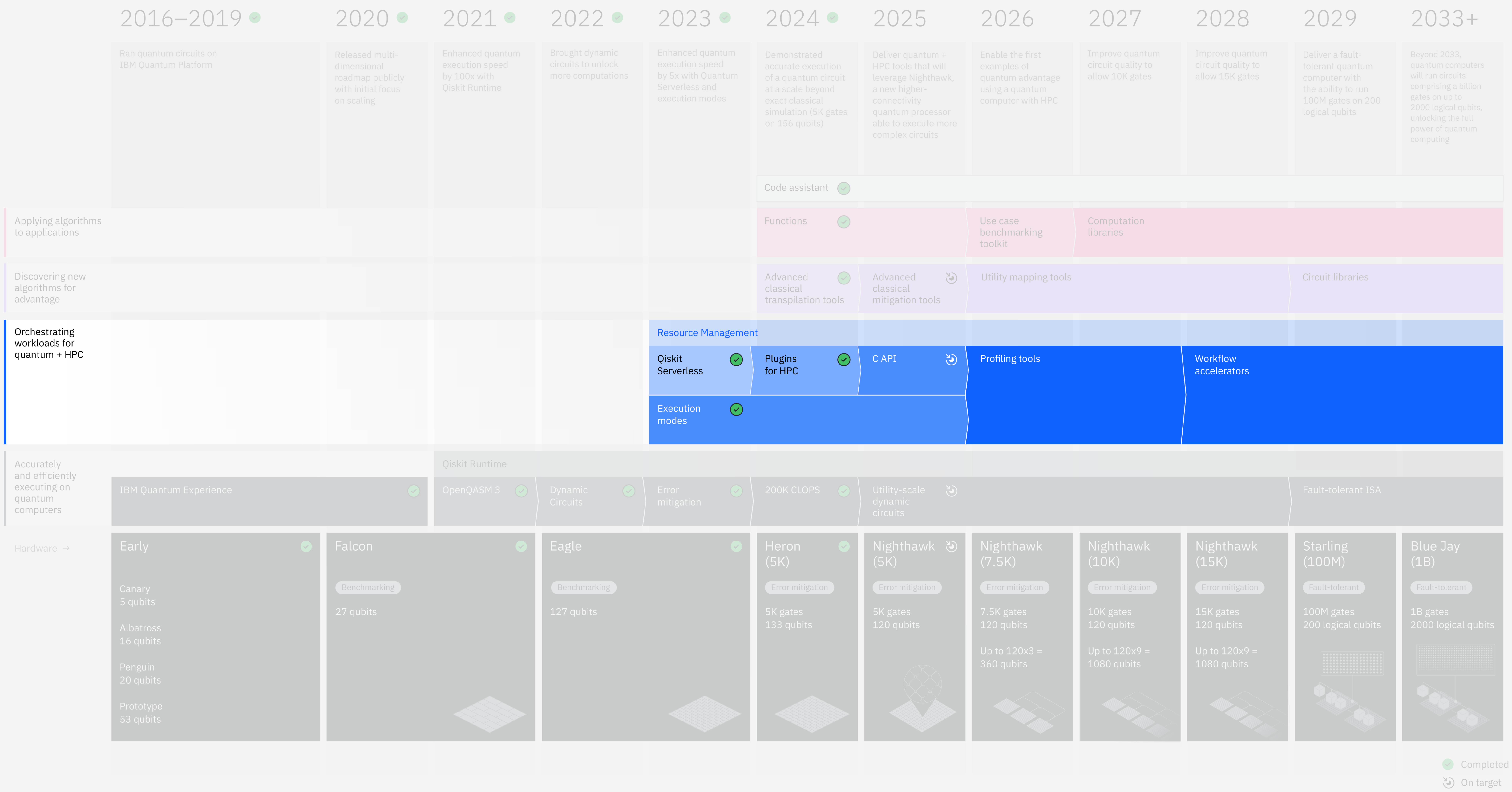
IBM **Quantum**

Running quantum workloads requires infrastructure that coordinates quantum resources with scalable classical resources.

In 2025, we have already released initial portions of the C-API, enabling users to write Qiskit code in C, which is widely used for HPC. Soon, users will be able to write quantum and classical code in the same language and deploy it in an integrated system.

Moving into 2026 and beyond, we will introduce new profiling tools to help users monitor, verify, and debug workloads across quantum and classical resources.

In 2027 we will introduce workflow accelerators that deliver optimized quantum-classical execution pipelines for efficiently running similar tasks.



2025 Development Roadmap: Discovering new algorithms for advantage

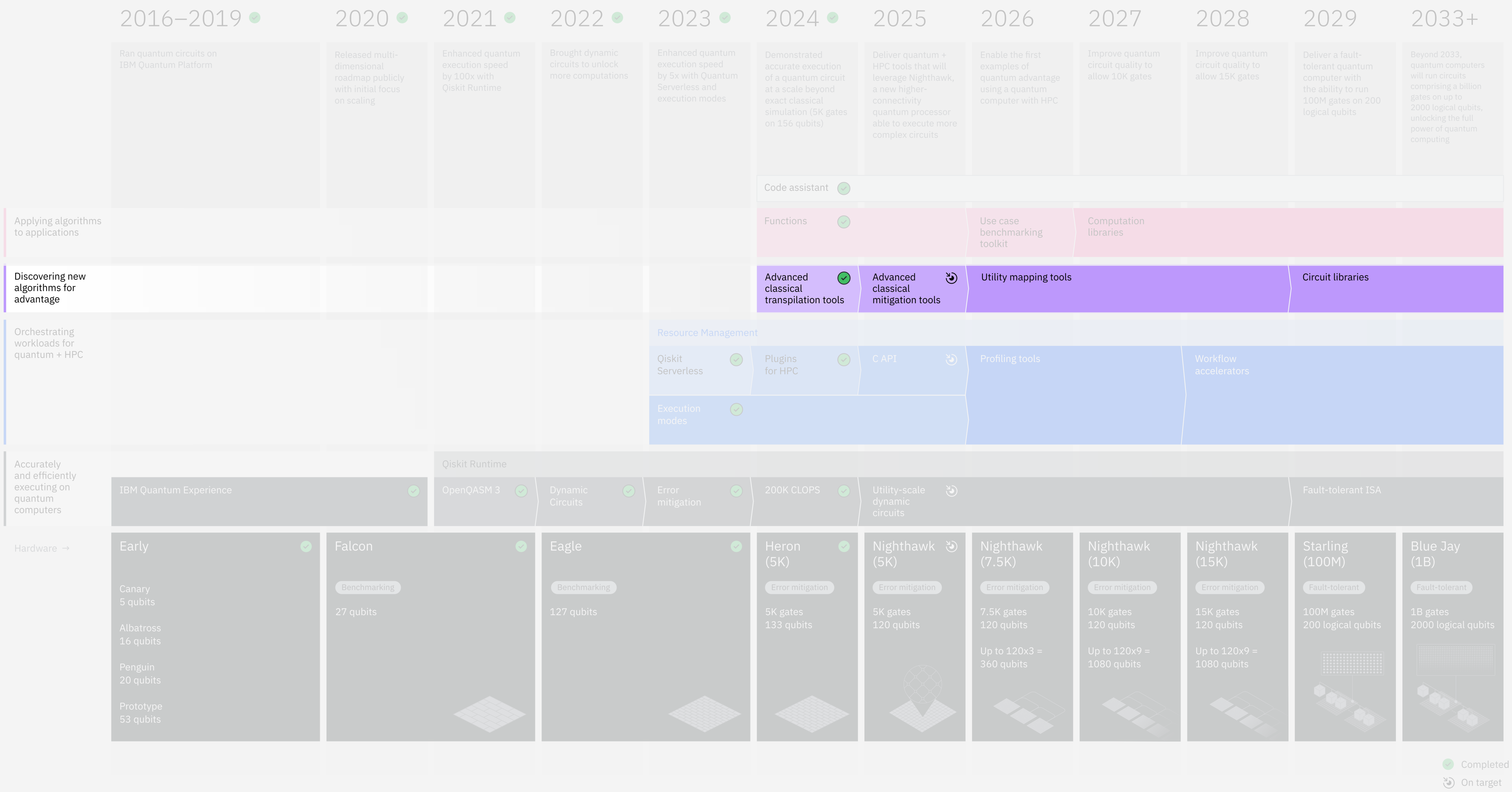
IBM **Quantum**

In 2024, we saw the emergence of powerful tools like AI transpilation passes and sample-based quantum diagonalization (SQD), which operate outside the runtime and use classical resources to suppress and mitigate errors.

In 2025, we expect these tools to mature further. We plan to expand on error mitigation capabilities that leverage advanced classical subroutines to mitigate errors outside the runtime. These will help users identify circuit types and characteristics that scale prior to fault tolerance.

In 2026, we will introduce utility mapping tools. These support the exploration and design of new algorithms by mapping problems to circuits that also scale prior to fault tolerance.

By 2029, we expect to provide libraries that offer an expanded, generalized set of circuits ideal for execution on fault-tolerant processors.



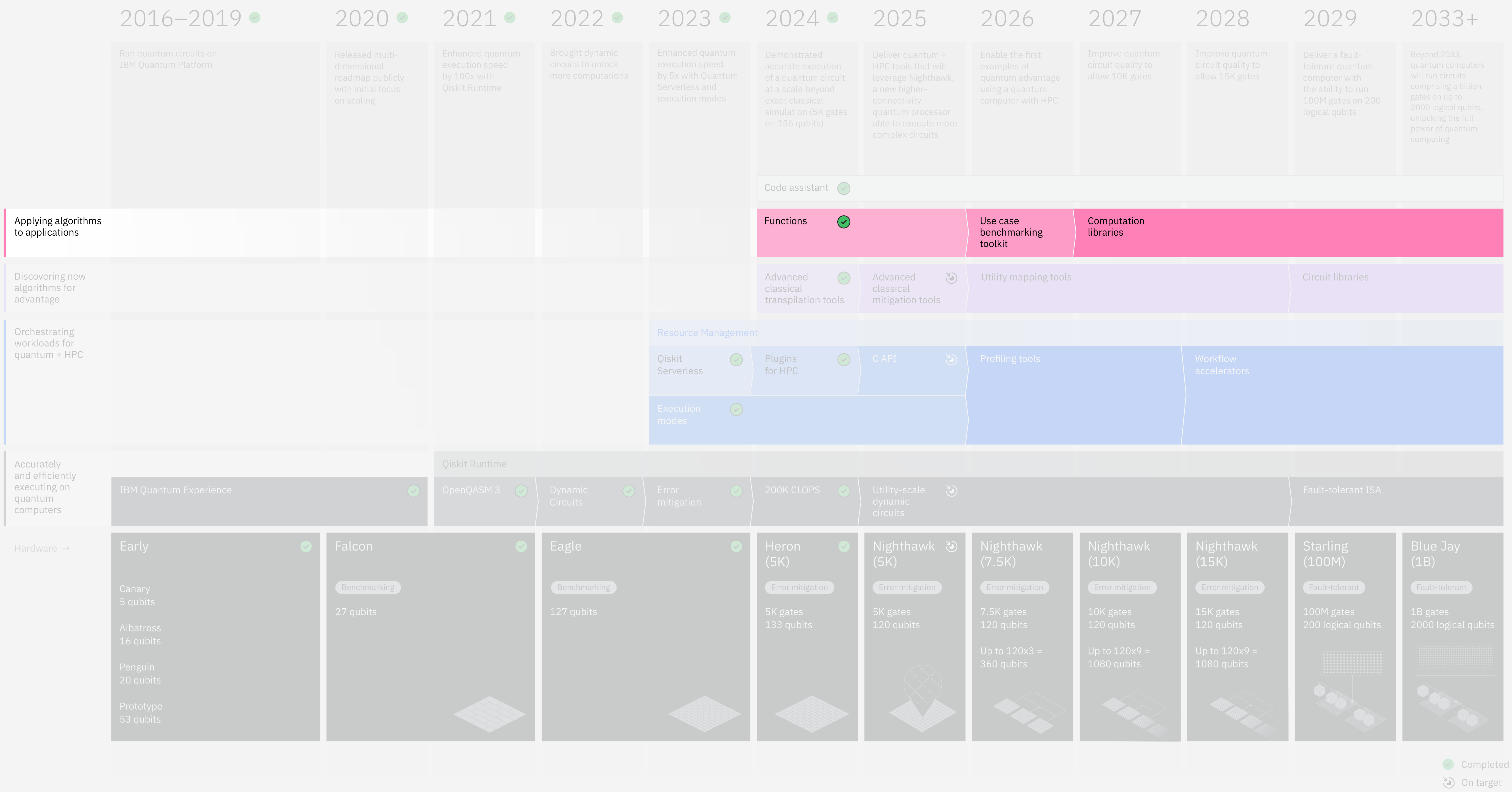
2025 Development Roadmap: Applying algorithms to applications

IBM **Quantum**

In 2024, we successfully delivered the Qiskit Functions Service to our Premium Plan users. In 2025, we will enhance it with new functions.

By the end of 2025, we will have established candidates for quantum advantage, as shown on our innovation roadmap. In 2026, we will 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.

In 2027, we will introduce computation libraries. These provide abstractions—mathematical subroutines for applications—that integrate with popular existing computational libraries. This will support collaboration, integration, and help users more efficiently build and orchestrate workflows across classical and quantum compute resources.



2025 Innovation Roadmap→

2025 Innovation Roadmap: Hardware

IBM Quantum

IBM Quantum Loon debuts 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.

Capitalizing on this improved connectivity, IBM has developed a scalable error-correcting code that outperforms earlier methods. This advancement strengthens our confidence in achieving large-scale, fault-tolerant quantum computing by 2029.

		Software innovation	Hardware innovation	Hardware innovation
2016–2019 (Completed)	Ran quantum circuits on IBM Quantum Platform	IBM Quantum Experience (Completed)	Early (Completed): Canary 5 qubits; Albatross 16 qubits; Penguin 20 qubits; Prototype 53 qubits	
		Qiskit (Completed): Open-source SDK for building and compiling circuits for quantum hardware	Falcon (Completed): Demonstrate scaling with I/O routing with bump bonds	
2020 (Completed)	Released multi-dimensional roadmap publicly with initial focus on scaling	Application modules (Completed): Modules for domain specific application and algorithm workflows	Hummingbird (Completed): Demonstrate scaling with multiplexing readout	
2021 (Completed)	Enhanced quantum execution speed by 100x with Qiskit Runtime	Qiskit Runtime (Completed): Performance and abstraction through primitives	Eagle (Completed): Demonstrate scaling with MLW and TSV	Egret (Completed): Tunable coupler demonstration
2022 (Completed)	Brought dynamic circuits to unlock more computations	Quantum Serverless (Completed): Demonstrate concepts of managing quantum and cloud classical compute for an end to end workflow	Osprey (Completed): Enabling scaling with high density signal delivery	
2023 (Completed)	Enhanced quantum execution speed by 5x with Quantum Serverless and execution modes	AI-enhanced quantum (Completed): Prototype demonstrations of AI-enhanced circuit transpilation	Condor (Completed): Single-system scaling and fridge capacity	Heron (Completed): Architecture based on tunable couplers
2024 (Completed)	Demonstrated accurate execution of a quantum circuit at a scale beyond exact classical simulation (5K gates on 156 qubits)	HPC-Quantum integration (Completed): Realize an integration of classical HPC and a quantum computer at utility scale	Flamingo (Completed): Demonstrate scaling with l-couplers	Crossbill (Completed): Demonstrate m-couplers
2025	Deliver quantum + HPC tools that will leverage Nighthawk, a new higher-connectivity quantum processor able to execute more complex circuits	Advantage candidates (On target): Define problem types for advantage in 2026	**Loon** (On target): Demonstrate c-couplers and next-generation packaging for FTQC	
2026	Enable the first examples of quantum advantage using a quantum computer with HPC	Error correction decoder: Demonstrate a real-time error correction decoder	Kookaburra: Demonstrate a complete module consisting of a logical processing unit and quantum memory	
2027	Improve quantum circuit quality to allow 10K gates	Workflow accelerator: Demonstrate a workflow accelerator that streamlines execution for a known advantage workflow	Cockatoo: Demonstrate entanglement of modules using a universal adapter	
2028	Improve quantum circuit quality to allow 15K gates	Fault-tolerant ISA: Demonstrate a complete instruction set architecture including magic state distillation for FTQC	Starling: Demonstrate multiple modules and magic state distillation	
2029	Deliver a fault-tolerant quantum computer with the ability to run 100M gates on 200 logical qubits			
2033+	Beyond 2033, quantum computers will run circuits comprising a billion gates on up to 2000 logical qubits, unlocking the full power of quantum computing			

Completed
On target

2025 Innovation Roadmap: Software, algorithms, and workflows

IBM **Quantum**

In 2025, we are conducting research to shortlist candidate algorithms to demonstrate quantum advantage in 2026.

In 2026, we aim to demonstrate the first examples of quantum advantage using a quantum computer with HPC.

At the same time, we will prototype our error correction decoder. This decoder will enable real-time error correction—a key capability for scalable, fault-tolerant quantum computing.

In 2027, we will prototype workflow acceleration strategies to streamline executions for known advantage workflows. This will help optimize execution across quantum and classical resources, saving developers valuable compute time.

In 2028, we will prototype a fault-tolerant instruction set architecture on our Starling proof-of-concept, to be released the following year.

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Hardware innovation	**Early** Canary 5 qubits; Albatross 16 qubits; Penguin 20 qubits; Prototype 53 qubits	**Falcon** Demonstrate scaling with I/O routing with bump bonds	**Hummingbird** Demonstrate scaling with multiplexing readout	**Eagle** Demonstrate scaling with MLW and TSV	**Osprey** Enabling scaling with high density signal delivery	**Condor** Single-system scaling and fridge capacity	**Flamingo** Demonstrate scaling with l-couplers	**Loon** Demonstrate c-couplers and next-generation packaging for FTQC	**Kookaburra** Demonstrate a complete module consisting of a logical processing unit and quantum memory	**Cockatoo** Demonstrate entanglement of modules using a universal adapter	**Starling** Demonstrate multiple modules and magic state distillation		
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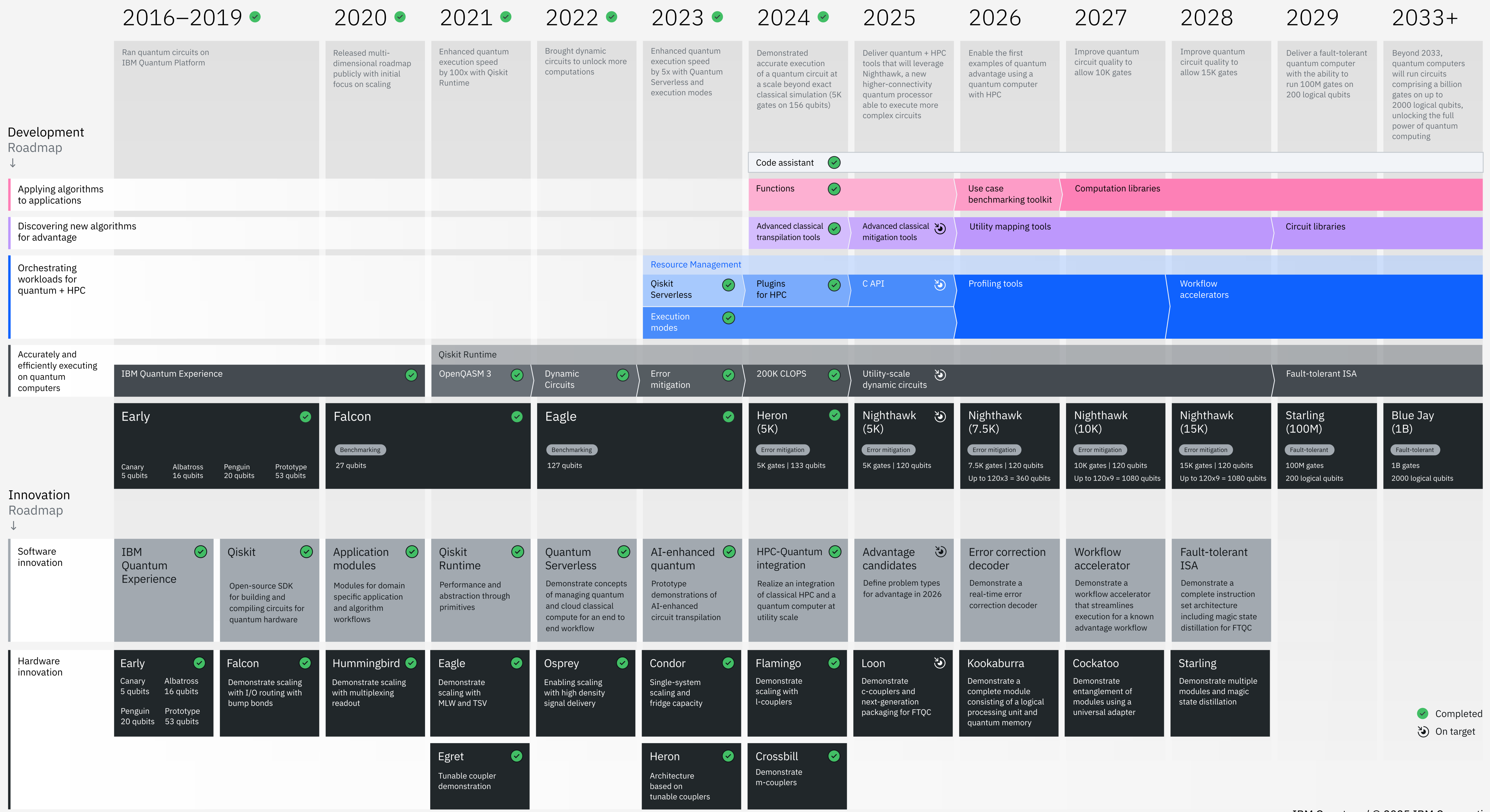

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