Preparing for the Quantum Era - From Opportunity to Action

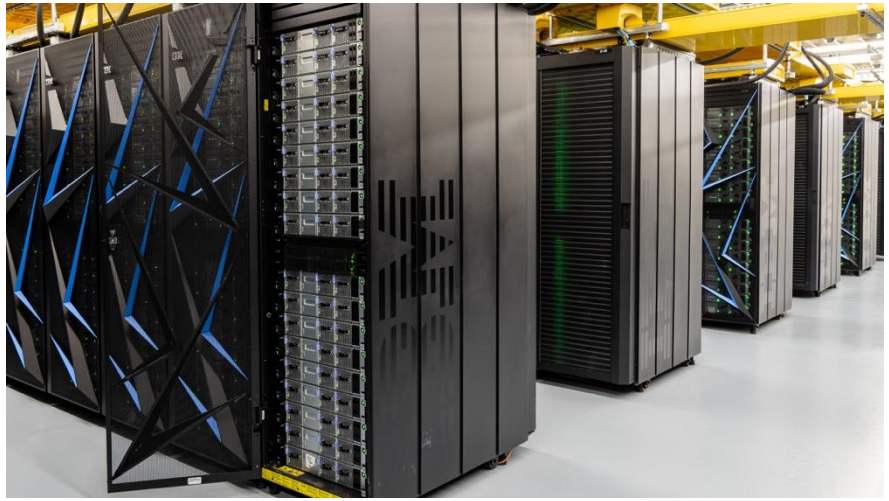
Dr. Heike Riel
IBM Fellow
Head Quantum and AI Technologies
IBM Research

hei@zurich.ibm.com

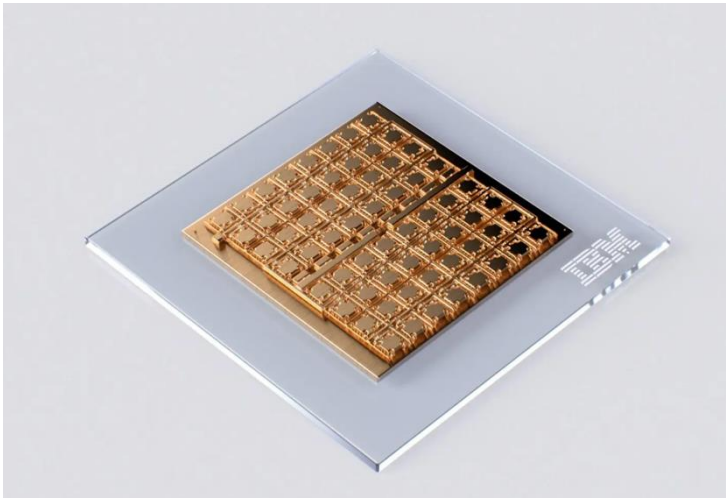


Quantum Computing

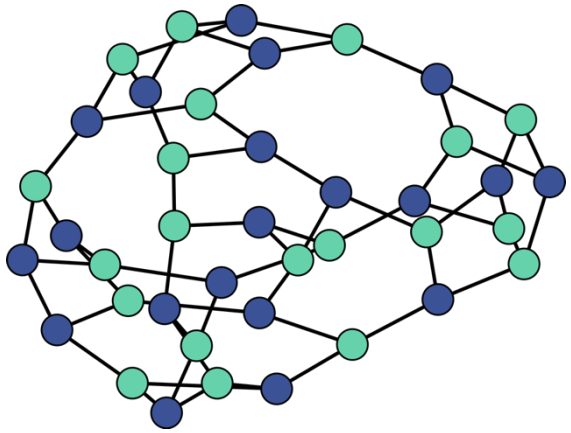
Critical for Every Business



High Performance Computing



Artificial Intelligence



Algorithms

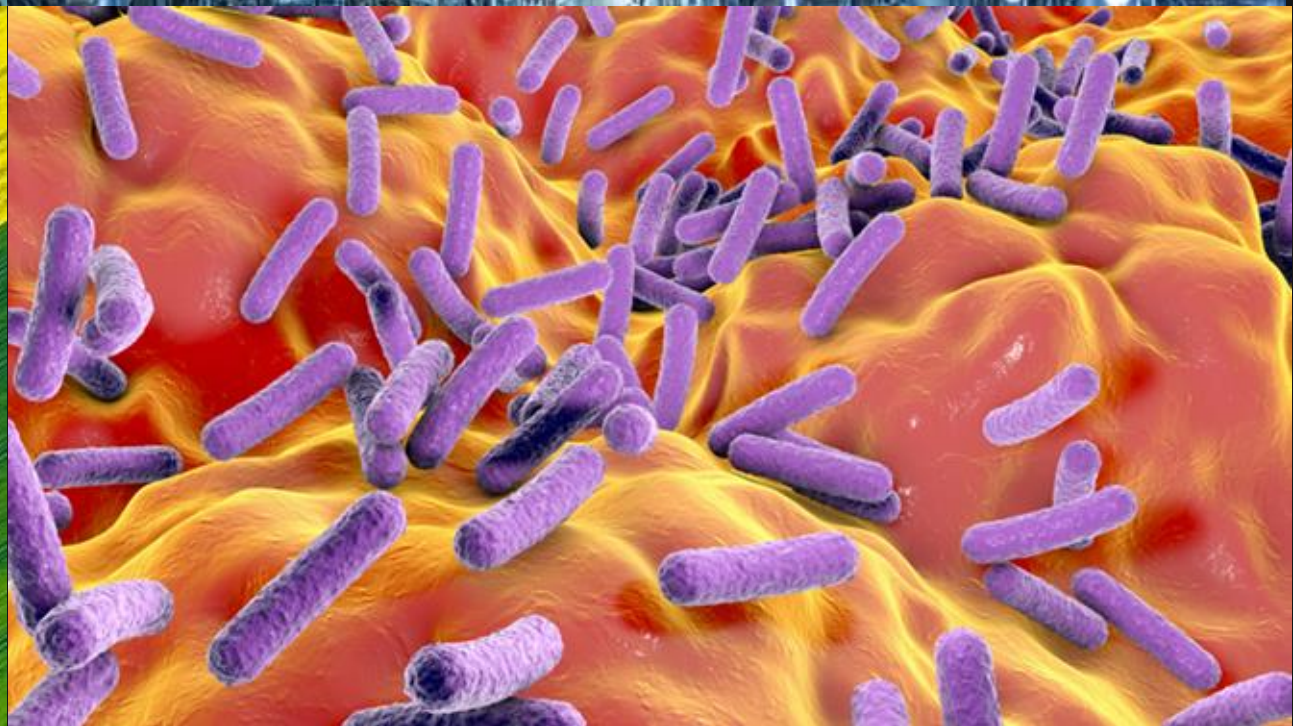
There are still intractable problems !!

© 2026 IBM Corporation





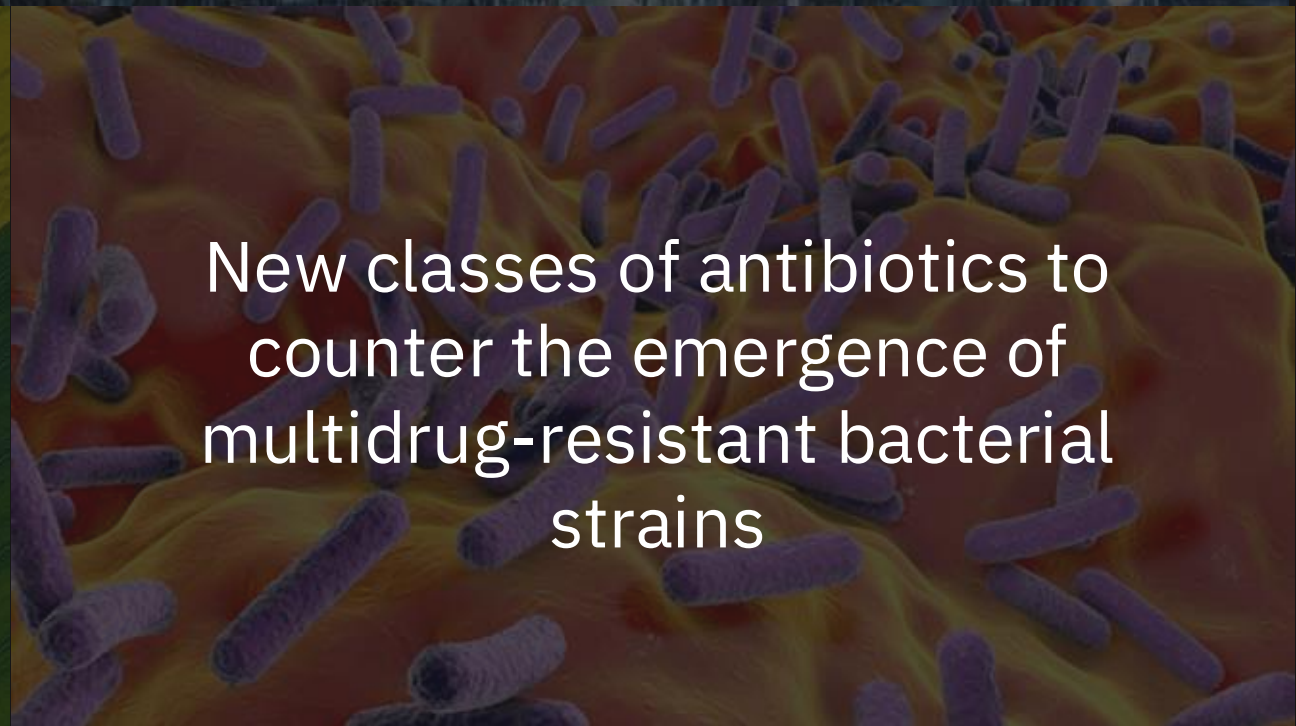





Better financial models to improve stability, predictability and growth of world economies


New catalysts to make CO_2 conversion into hydrocarbons more efficient and selective

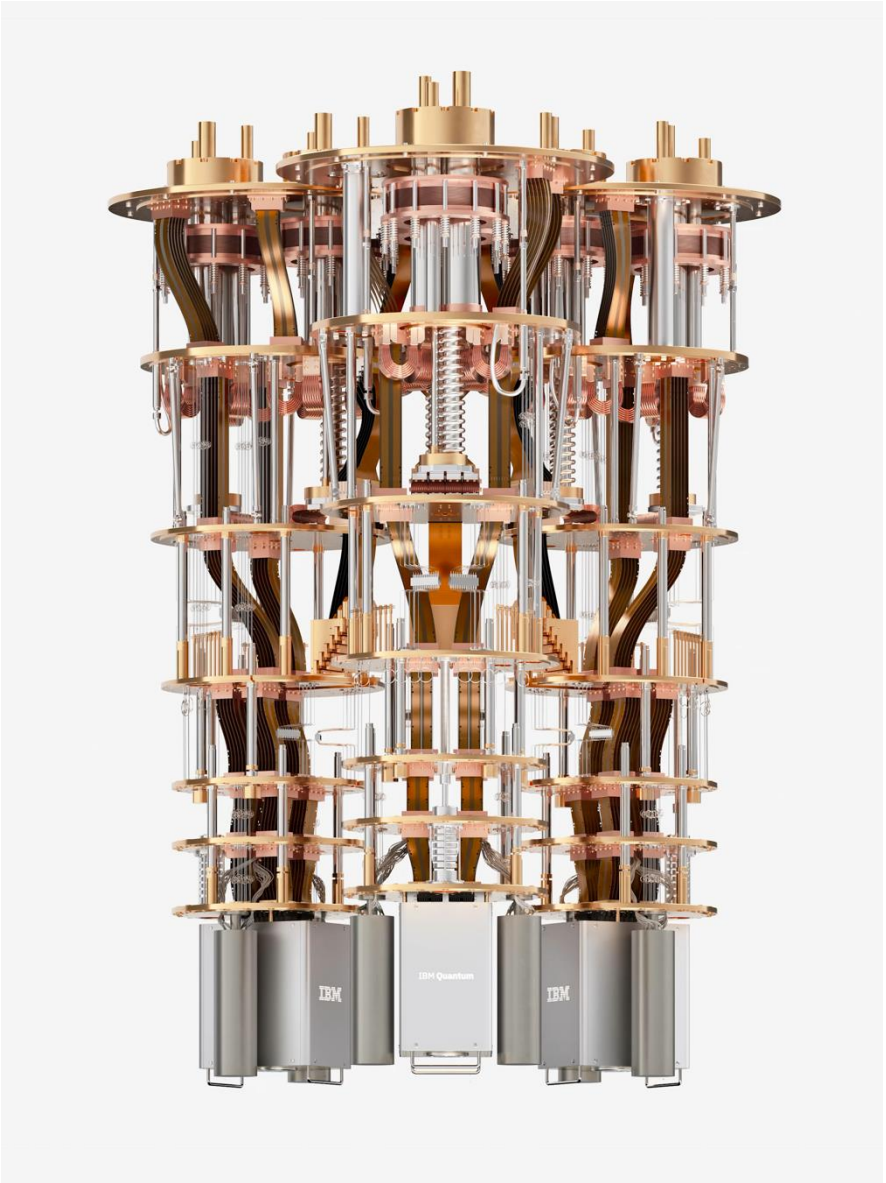

Improved nitrogen-fixation process for creating ammonia-based fertilizer


New classes of antibiotics to counter the emergence of multidrug-resistant bacterial strains

Quantum Computing

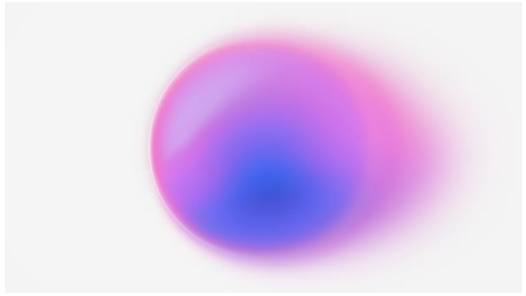
Computing ReDefined

A radically new approach to computing

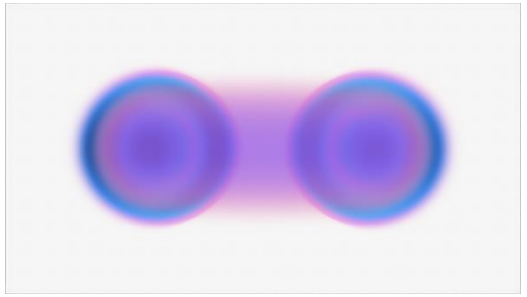


IBM Quantum System Two triple-chandelier render

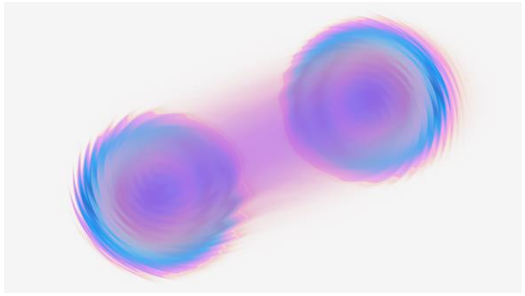
Uniquely quantum



Superposition
A quantum system existing in multiple states simultaneously until it is measured



Entanglement
Information shared jointly between entangled pairs or groups



Interference
Interaction that affects likelihood of solutions

2^N



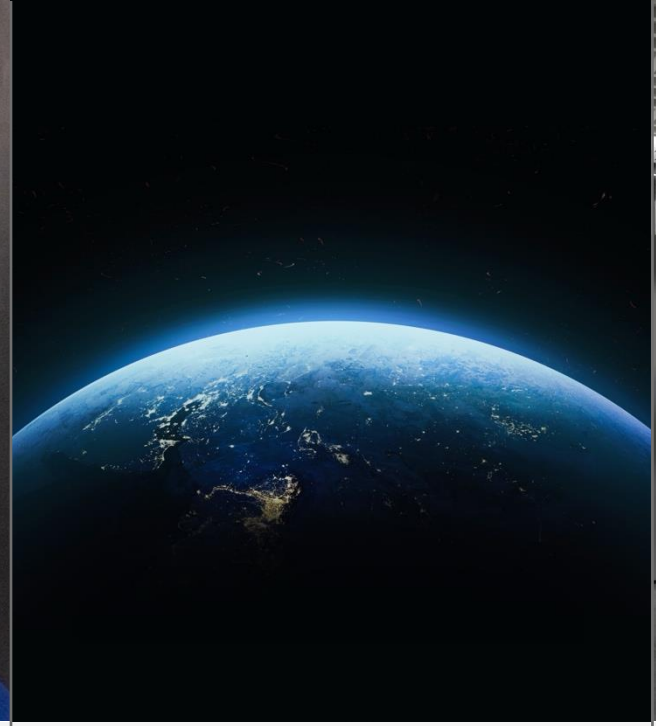
Modern laptop

30 qubits*



IBM Summit
Supercomputer

48 qubits*



All classical computers
on earth connected

60 qubits*

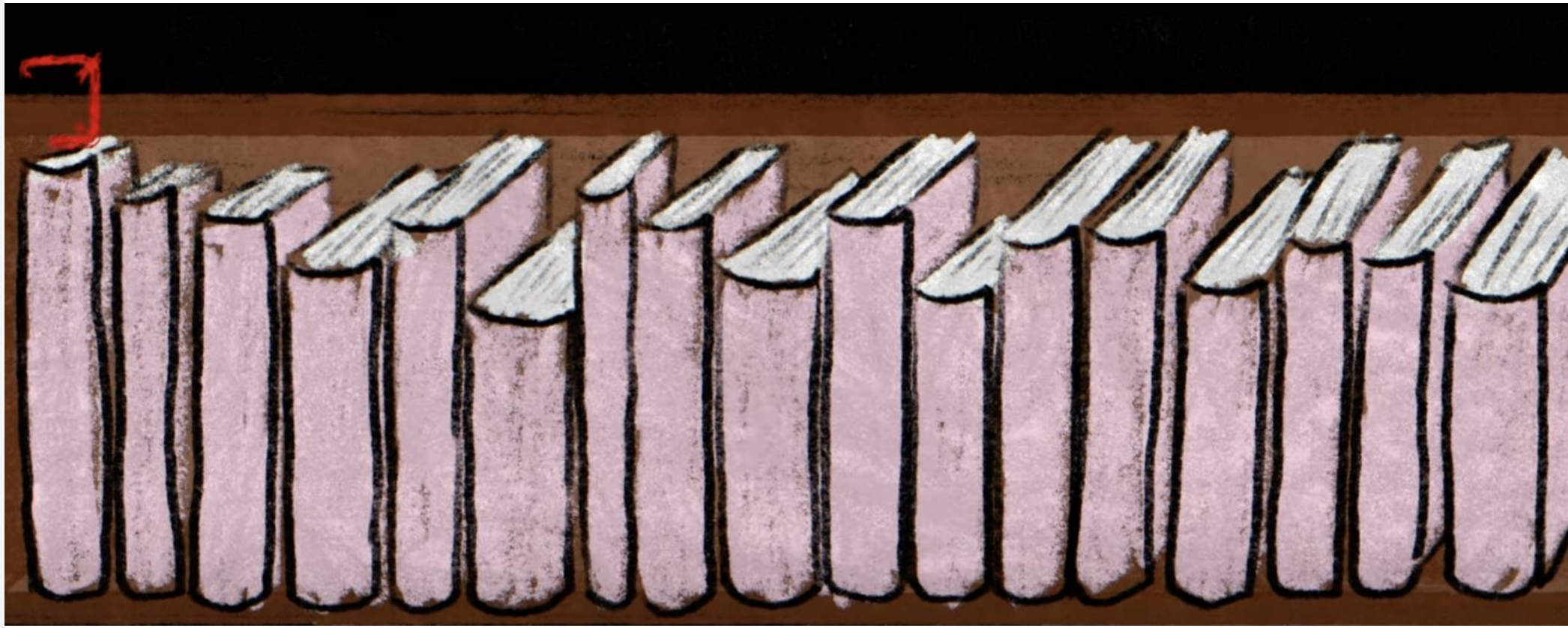


2029 IBM Quantum Starling

200 qubits*

* Logical qubits

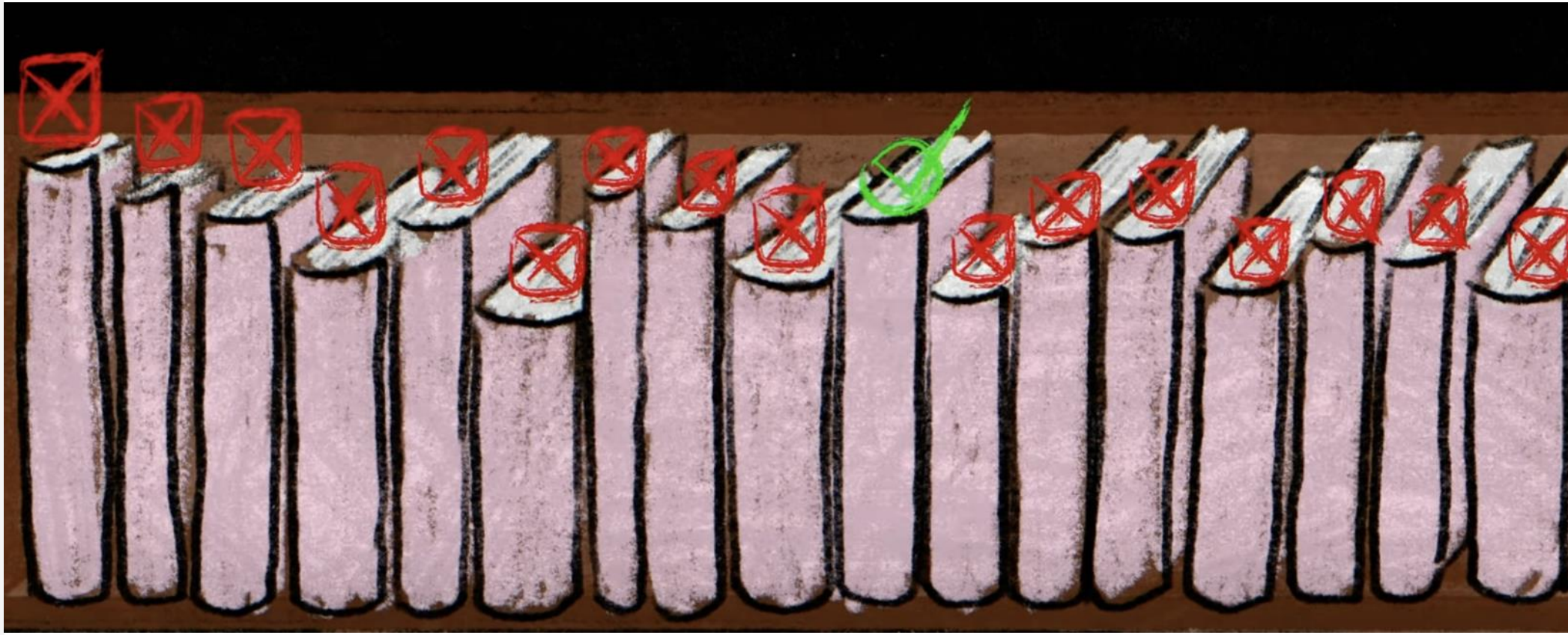
Finding a secret message in a book in a library



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Classical Computer:

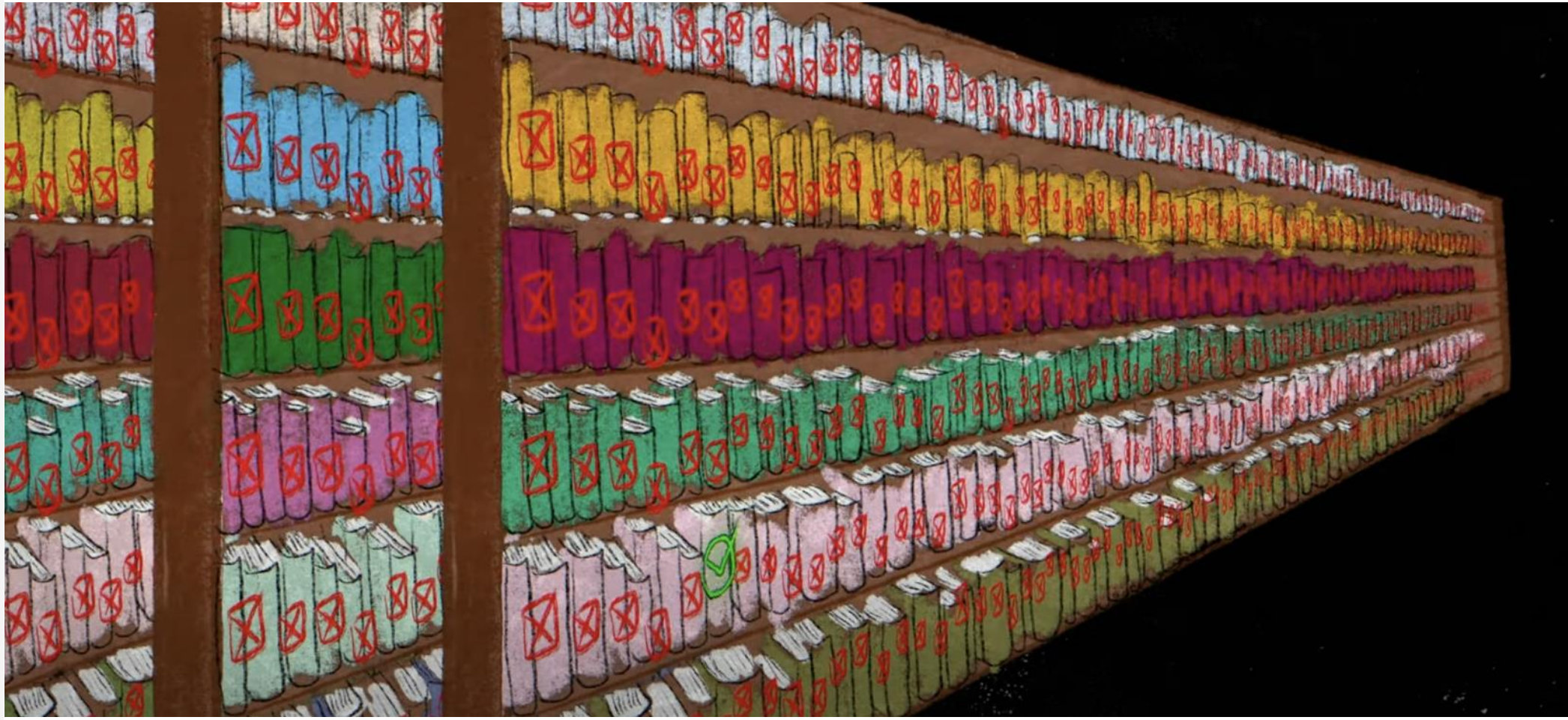
Open every book sequent-ially



© 2026 IBM Corporation

Quantum Computer:

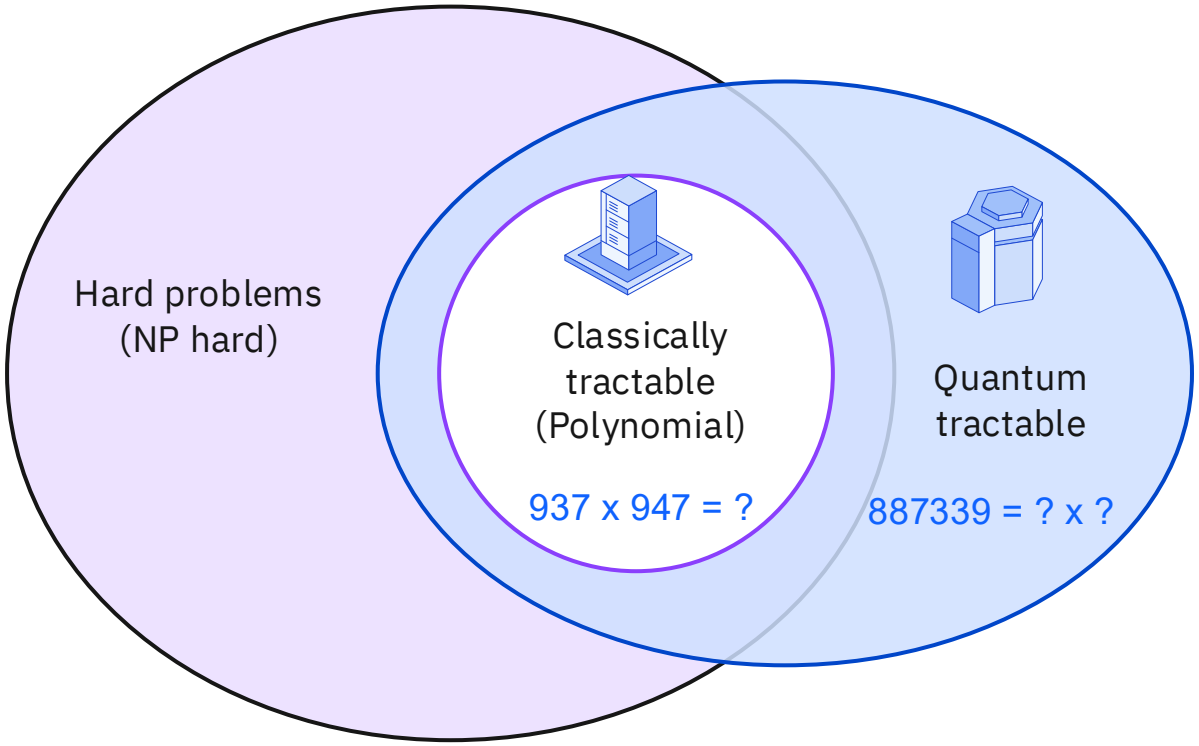
Open all books at the same time



© 2026 IBM Corporation

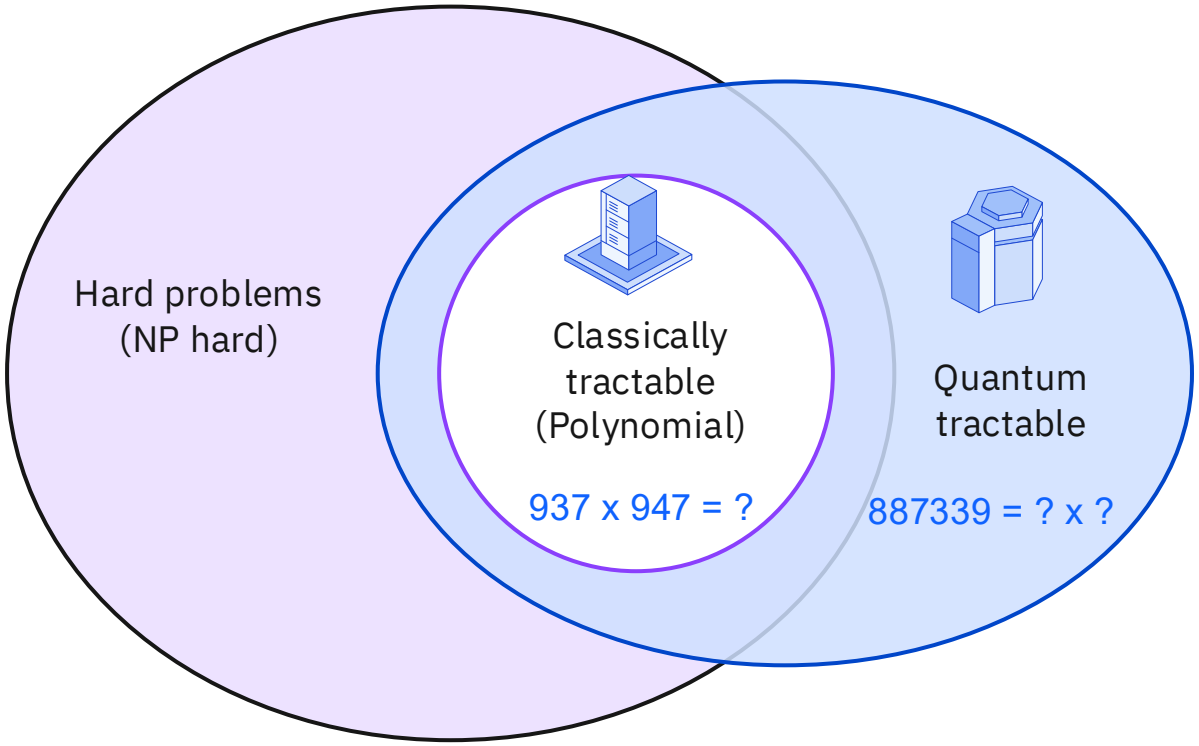
Quantum computational areas

No matter how powerful,
there are intractable problems classical computers simply cannot solve



Quantum computational areas

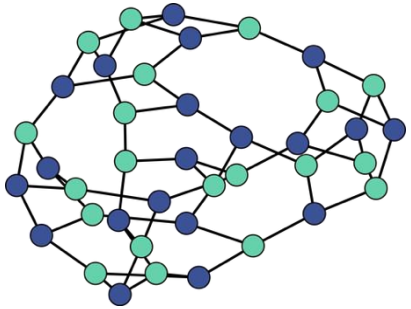
No matter how powerful,
there are intractable problems classical computers simply cannot solve



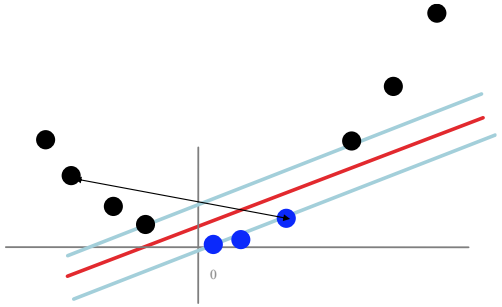
Hamiltonian simulation



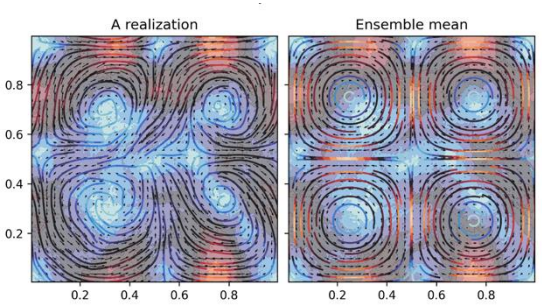
Optimization



Machine learning



Differential equations



Routing & Scheduling Optimization



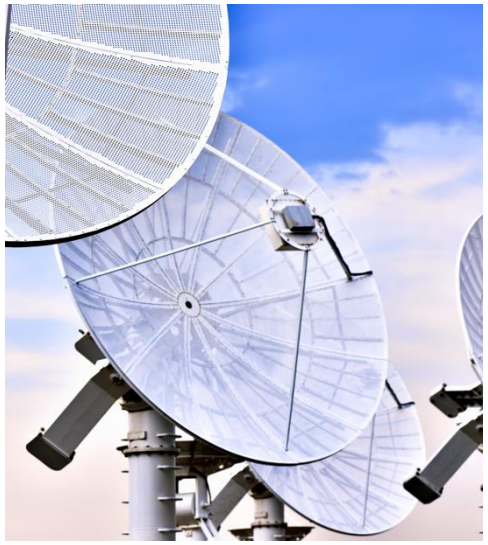
Predictive Maintenance



Satellite image classification



Rare events detection



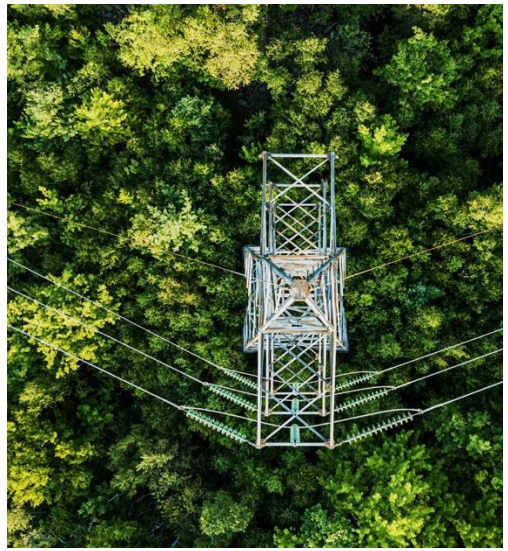
Battery design & development



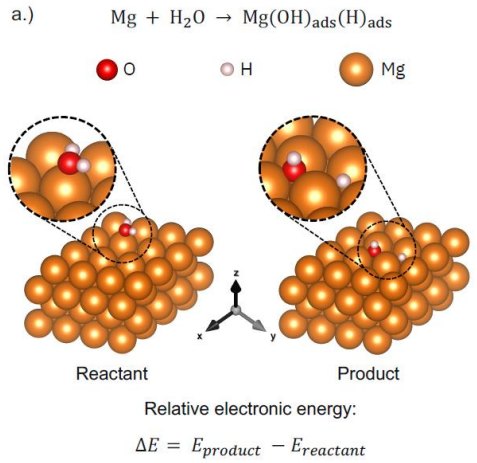
Derivative prizing & risk analysis



Optimize the world's rapidly decentralized energy infrastructure



Model corrosion reactions for magnesium, the lightest structural metal

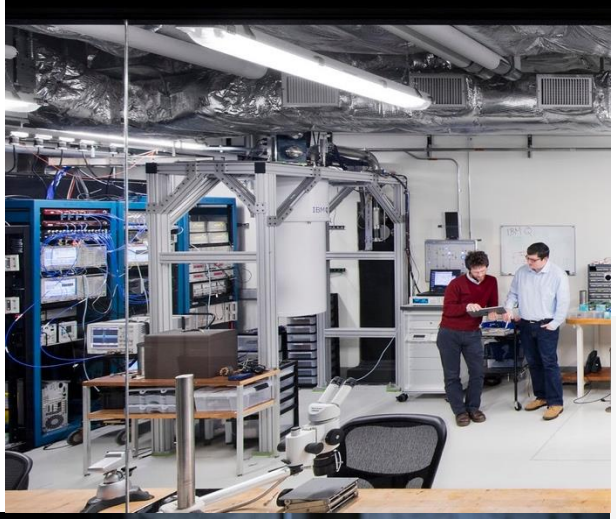


“Quantum computing – total economic impact estimated at $1.3 trillion to $2.7 trillion by 2035.”— BCG

Travel, transport, and logistics	Financial services	Advanced industries, insurance, Telecom, media, technology	Energy, environment and utilities	Pharmaceuticals and medical products
$200–400B	Risk management, Market simulation, Fraud, money laundering, ...: $400–600B	$50–100B	Oil & gas: $50–150B Electric Power: $50–150B	$80–400B Chemical $450-800B

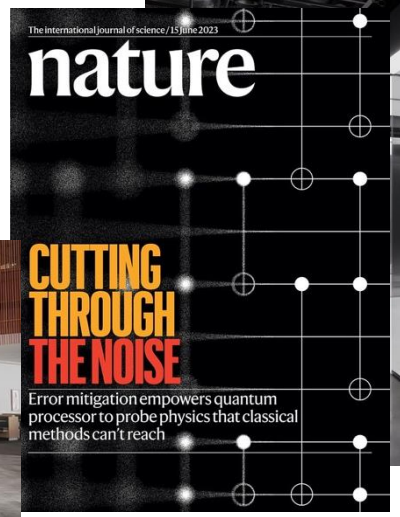
Source: https://www.mckinsey.com/featured-insights/the-rise-of-quantum-computing

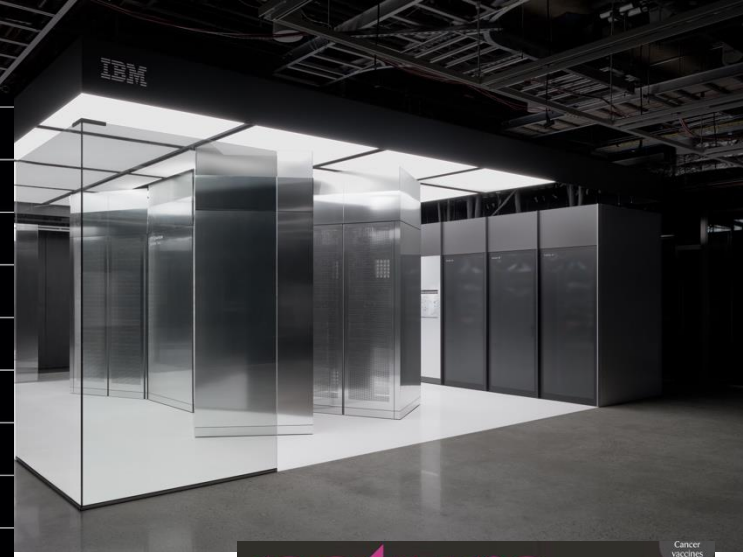
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The international journal of science / 15 June 2023
nature
CUTTING THROUGH THE NOISE
Error mitigation empowers quantum processor to probe physics that classical methods can't reach

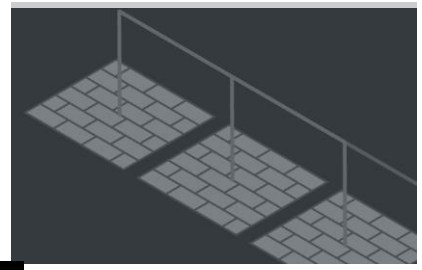


2016 → Now



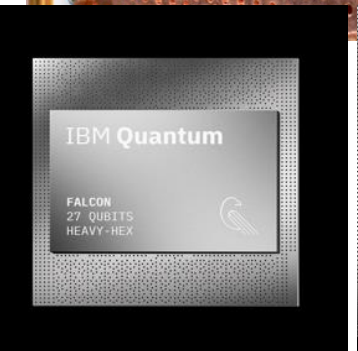


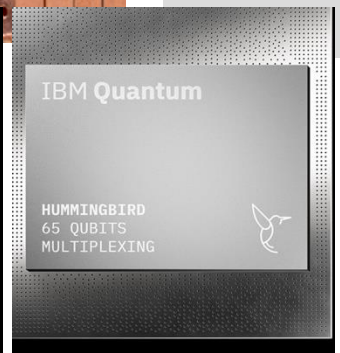





Qiskit SDK v1.1.1
Qiskit


nature
QUBIT QUOTA
Code cuts overhead for quantum error correction by 90%

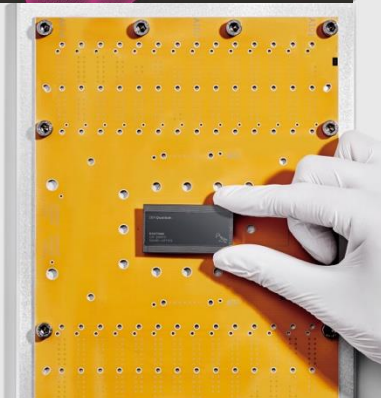

IBM Quantum
FALCON
27 QUBITS
HEAVY-HEX


IBM Quantum
HUMMINGBIRD
65 QUBITS
MULTIPLEXING


IBM Quantum
EAGLE
127 QUBITS
PACKAGING


IBM Quantum
CONDOR
1121 QUBITS
SCALE | YIELD





2

IBM Quantum Data Centers

Quantum computers for commercial use

- 90+ quantum systems deployed to date
- 31 quantum computers with 100+ qubit processors that can run circuits with >5000 two-qubit gates
- Average 97% availability across fleet
- Job success rate >99.5%

IBM US Quantum Data Center



IBM EU Quantum Data Center



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2

IBM Quantum Data Centers

Quantum Computational Center
University of Tokyo

Shin-Kawasaki, Japan
June 2021



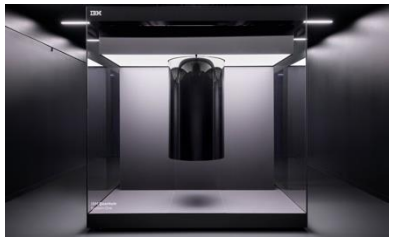
Discovery Accelerator
Cleveland Clinic

Ohio, USA
March 2023



Discovery Accelerator
PINQ [2]

Bromont, Canada
September 2023



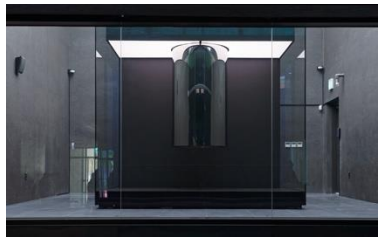
Quantum Computational Center
Rensselaer Polytechnic

Troy, New York
April 2024



Quantum Computational Center
Yonsei University

Seoul, South Korea
September 2024



10

Client-located systems

JHPC-quantum Riken

Kobe, Japan
May 2025



IBM-Euskadi Quantum Computational Center

San Sebastián, Spain
October 2025



National Quantum Algorithm Center

Chicago, USA
Projected 2H 2026



ETH Zurich

Switzerland
Projected 12/2026



Quantum Valley Tech Park

Andhra Pradesh, India
Projected 1H 2027



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Switzerland will soon get its first IBM Quantum System Two

Lockheed Martin and IBM are launching a Swiss quantum innovation hub at ETH Zurich to advance research, industry collaboration, and workforce development.



- IBM Quantum System II with Nighthawk R2 processor comes to the ETHZ Quantum Innovation Hub Switzerland
- To be installed at the Swiss National Supercomputing Centre (CSCS)
- Expand quantum computing access across Swiss institutions to fuel the country's quantum ecosystem, research, and workforce

IBM Research | © 2026 IBM Corporation

https://www.ibm.com/quantum/blog/swiss-innovation-hub

Advancement of quantum computing

2016

Quantum is online

Quantum devices on the cloud, opening the path for quantum developers

2023

Quantum utility

Quantum computers run quantum programs beyond classical

5K operations on 100+ qubits

2026

Quantum is real

Provable scientific quantum advantage

Quantum applied to real use cases, simulating problems of interest

With clear separation and verifiability.

2029

Fault tolerance

>100 million operations with broad resistance to failures

IBM Research / © 2026 IBM Corporation


IBM Quantum

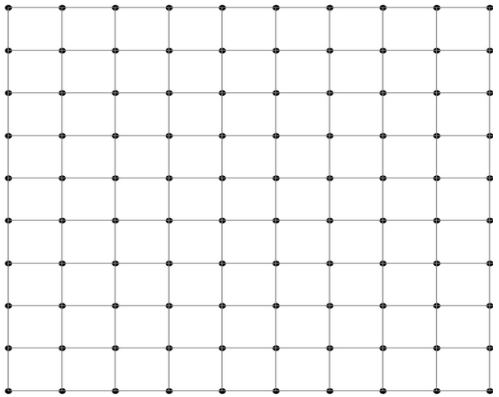
IBM Quantum Nighthawk r2

120 programmable qubits with square connectivity

458 physical qubits

On-chip reset critical for error correction

Now available on IBM Quantum Platform



100,000+

Max circuits per second

25x

Speedup in circuits per second compared to Heron

25x

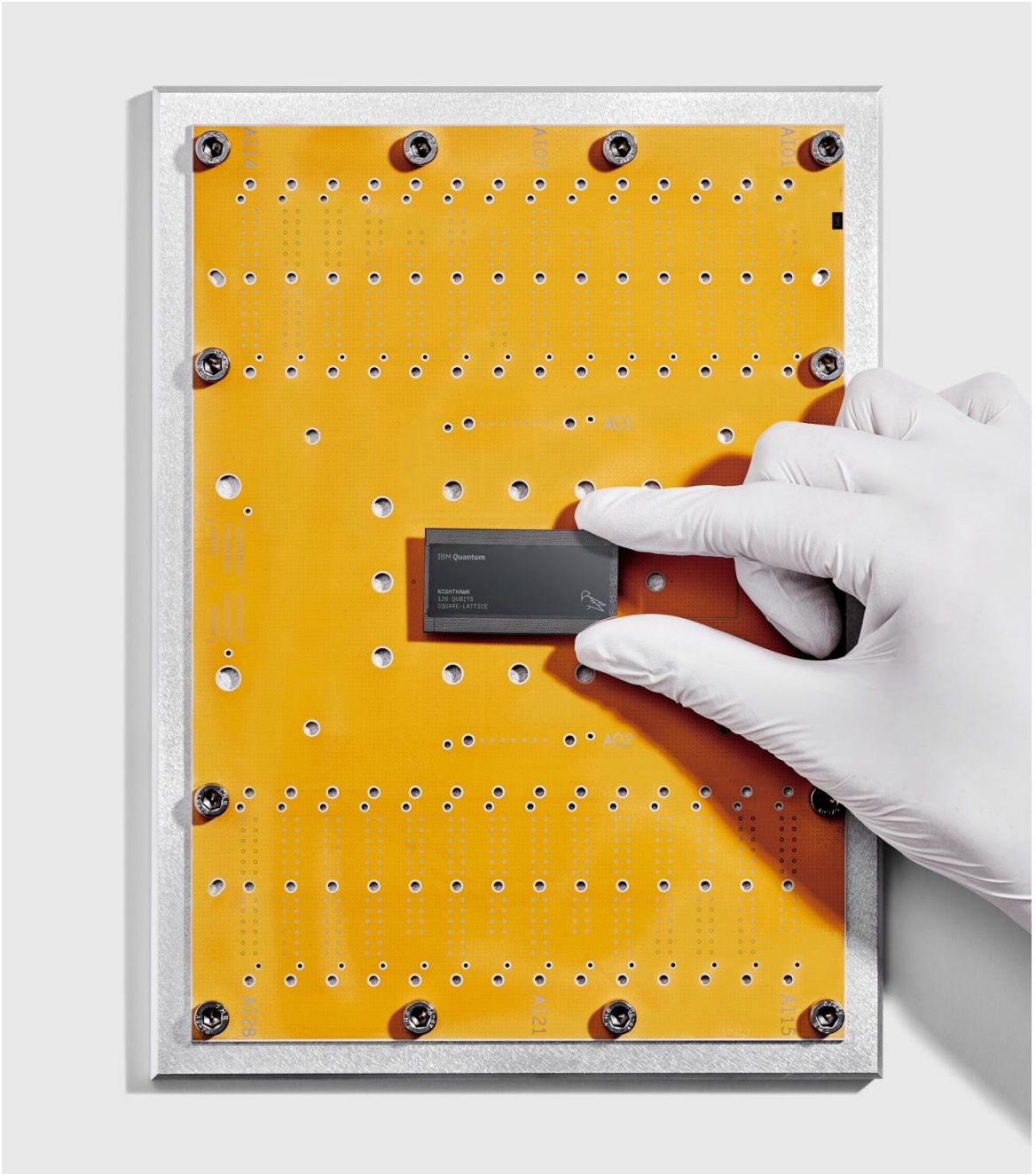
Improvement in initialization error compared to Heron

2.7e-3

Median 2Q error rates

>7500

Gates



IBM Quantum / © 2026 IBM Corporation

Development Roadmap

	2016–2019 ✓	2020 ✓	2021 ✓	2022 ✓	2023 ✓	2024 ✓	2025 ✓	2026	2027	2028	2029	2033+
	Ran quantum circuits on IBM Quantum Platform	Released multi-dimensional roadmap publicly with initial focus on scaling	Enhanced quantum execution speed by 100x with Qiskit Runtime	Brought dynamic circuits to unlock more computations	Enhanced quantum execution speed by 5x with Quantum Serverless and execution modes	Demonstrated accurate execution of a quantum circuit at a scale beyond exact classical simulation (5K gates on 156 qubits)	Deliver quantum + HPC tools that will leverage Nighthawk, a new higher-connectivity quantum processor able to execute more complex circuits	Enable the first examples of quantum advantage using a quantum computer with HPC	Improve quantum circuit quality to allow 10K gates	Improve quantum circuit quality to allow 15K gates	Deliver a fault-tolerant quantum computer with the ability to run 100M gates on 200 qubits	Beyond 2033, quantum computers will run circuits comprising a billion gates on up to 2000 qubits, unlocking the full power of quantum computing
Applying algorithms to applications						Code assistant ✓						
						Functions ✓		Use case benchmarking toolkit ↻	Computation libraries			
Discovering new algorithms for advantage						Advanced classical transpilation tools ✓	Advanced classical mitigation tools ✓	Utility mapping tools ↻			Circuit libraries	
Orchestrating workloads for quantum + HPC					Qiskit Serverless ✓	Plugins for HPC ✓	API ✓	Profiling tools ↻		Workflow accelerators		
					Execution modes ✓							
Accurately and efficiently executing on quantum computers	IBM Quantum Experience ✓		Qiskit Runtime									
			OpenQASM 3 ✓	Dynamic Circuits ✓	Error mitigation ✓	200K CLOPS ✓	Utility-scale dynamic circuits ✓				Fault-tolerant ISA	
Hardware →	Early ✓ Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	Falcon ✓ Benchmarking 27 qubits	Eagle ✓ Benchmarking 127 qubits	Heron (5K) ✓ Error mitigation 5K gates 133 qubits	Nighthawk (5K) ✓ Error mitigation 5K gates 120 qubits	Nighthawk (7.5K) ↻ Error mitigation 7.5K gates 120 qubits Up to 120x3 = 360 qubits	Nighthawk (10K) Error mitigation 10K gates 120 qubits Up to 120x9 = 1080 qubits	Nighthawk (15K) Error mitigation 15K gates 120 qubits Up to 120x9 = 1080 qubits	Starling (100M) Fault-tolerant 100M gates 200 qubits	Blue Jay (1B) Fault-tolerant 1B gates 2000 qubits		

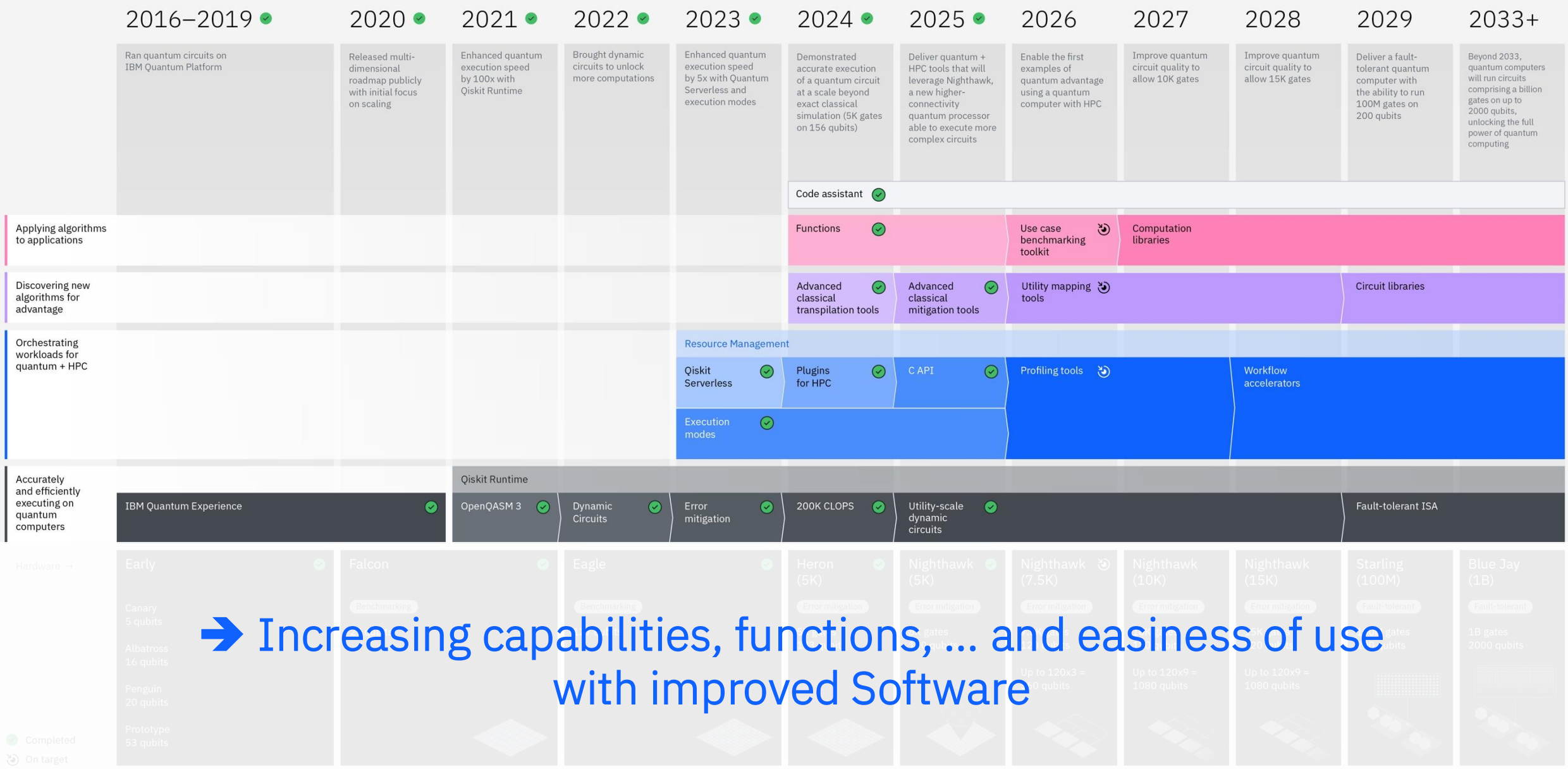
➔ Increasing performance of Quantum Hardware

✓ Completed
↻ On target

© 2026 IBM Corporation

✓ Completed
↻ On target

Development Roadmap



➔ Increasing capabilities, functions,... and easiness of use with improved Software

© 2026 IBM Corporation

Completed
On target

Development Roadmap

	2016–2019 ✓	2020 ✓	2021 ✓	2022 ✓	2023 ✓	2024 ✓	2025 ✓	2026	2027	2028	2029	2033+
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						Code assistant ✓						
Applying algorithms to applications						Functions ✓		Use case benchmarking toolkit ↻	Computation libraries			
Discovering new algorithms for advantage						Advanced classical transpilation tools ✓	Advanced classical mitigation tools ✓	Utility mapping tools ↻			Circuit libraries	
Orchestrating workloads for quantum + HPC					Resource Management							
					Qiskit Serverless ✓	Plugins for HPC ✓	C API ✓	Profiling tools ↻		Workflow accelerators		
					Execution modes ✓							
Accurately and efficiently executing on quantum computers			Qiskit Runtime									
	IBM Quantum Experience ✓		OpenQASM 3 ✓	Dynamic Circuits ✓	Error mitigation ✓	200K CLOPS ✓	Utility-scale dynamic circuits ✓				Fault-tolerant ISA	
Hardware →	Early ✓ Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	Falcon ✓ Benchmarking 27 qubits	Eagle ✓ Benchmarking 127 qubits			Heron (5K) ✓ Error mitigation 5K gates 133 qubits	Nighthawk (5K) ✓ Error mitigation 5K gates 120 qubits	Nighthawk (7.5K) ↻ Error mitigation 7.5K gates 120 qubits Up to 120x3 = 360 qubits	Nighthawk (10K) Error mitigation 10K gates 120 qubits Up to 120x9 = 1080 qubits	Nighthawk (15K) Error mitigation 15K gates 120 qubits Up to 120x9 = 1080 qubits	Starling (100M) Fault-tolerant 100M gates 200 qubits	Blue Jay (1B) Fault-tolerant 1B gates 2000 qubits

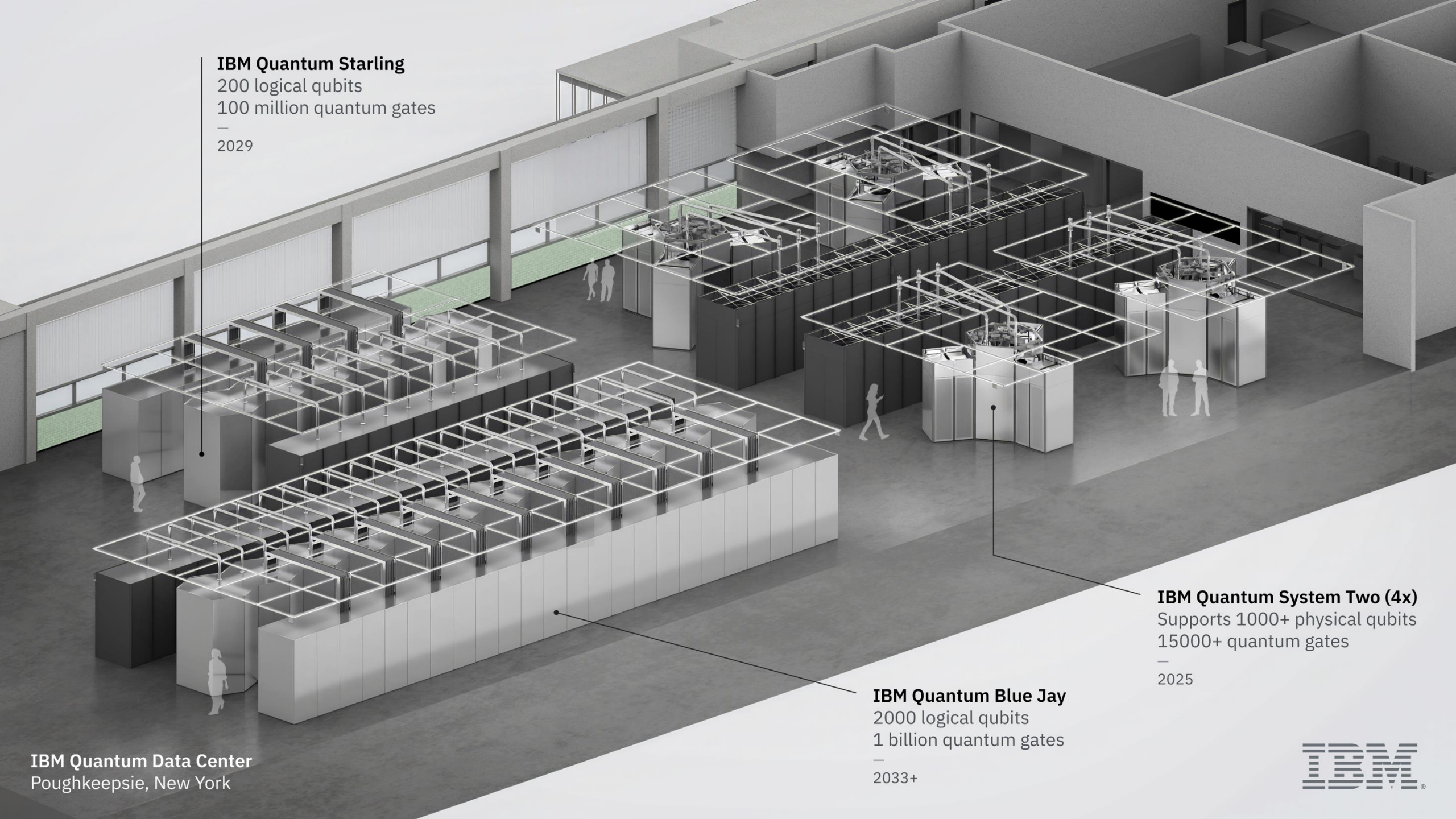
✓ Completed
↻ On target

© 2026 IBM Corporation

✓ Completed
↻ On target

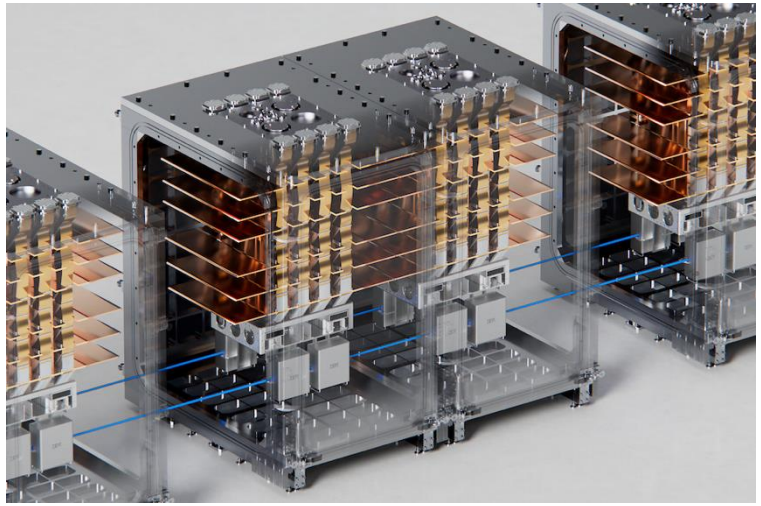
2029 ↴

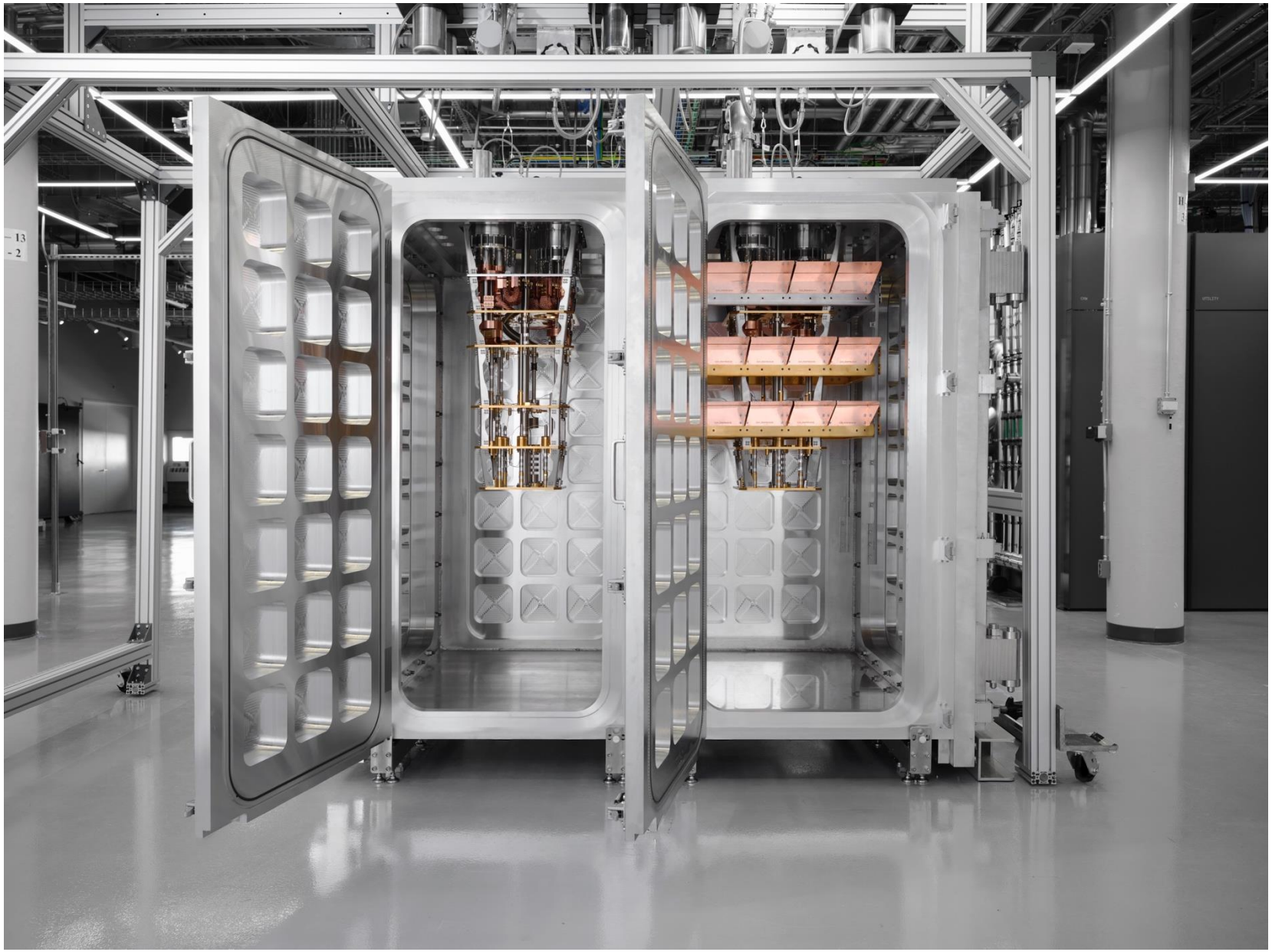
Large-scale fault-tolerant systems


IBM Quantum Starling
200 logical qubits
100 million quantum gates
—
2029
IBM Quantum System Two (4x)
Supports 1000+ physical qubits
15000+ quantum gates
—
2025
IBM Quantum Blue Jay
2000 logical qubits
1 billion quantum gates
—
2033+
IBM Quantum Data Center
Poughkeepsie, New York

Modular cryogenic architecture purpose-built for fault-tolerant quantum computing

- Modular architecture
- Efficient integration
- Flexible evolution
- Scalable deployment

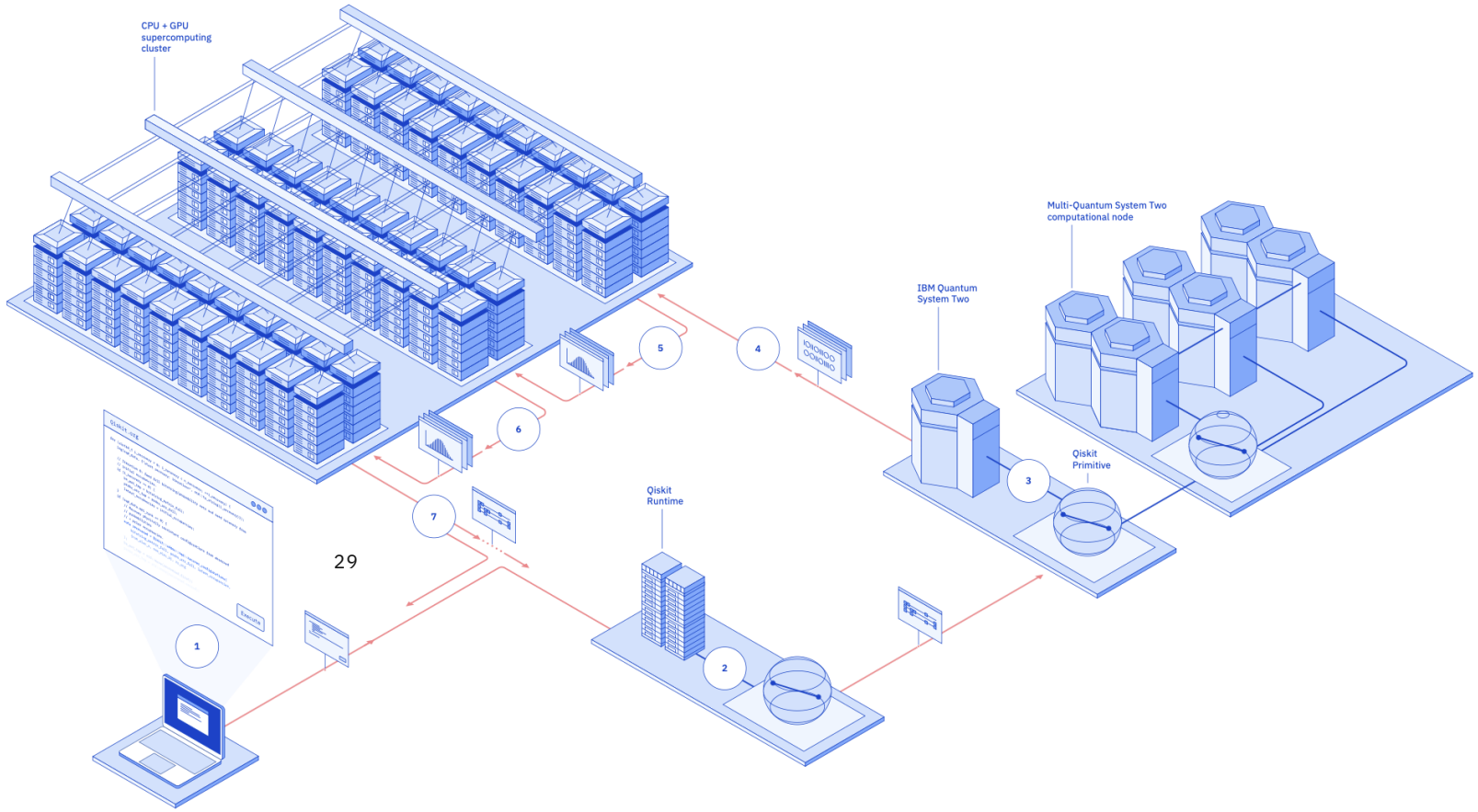




Read the informational sheet: https://ibm.biz/modular-cryo

IBM Quantum / © 2026 IBM Corporation

CPUs
+ GPUs
+ QPUs



Quantum-centric supercomputing

for accelerated scientific discovery

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Quantum Advantage:

A quantum computer performing an information-processing task more efficiently, cost-effectively, or accurately than the best-known classical computing methods.

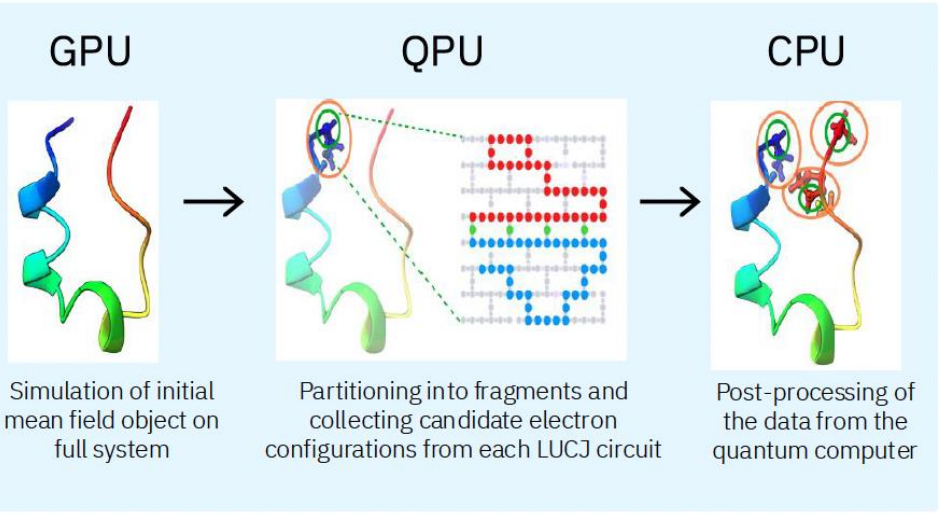
Pushing the scale of chemistry applications with quantum-cent supercomputing

IBM Quantum System 2



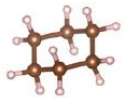
RIKEN Fugaku



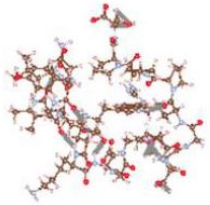




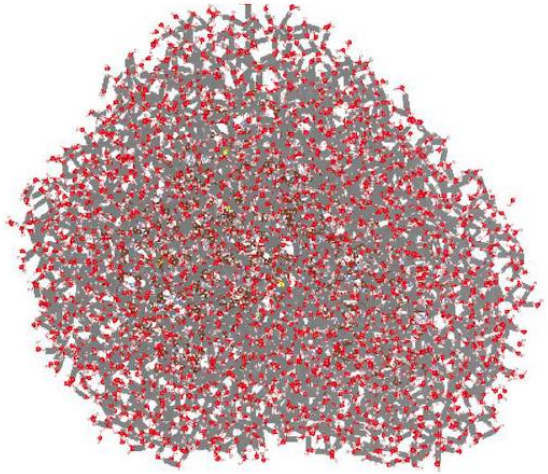
10 atoms



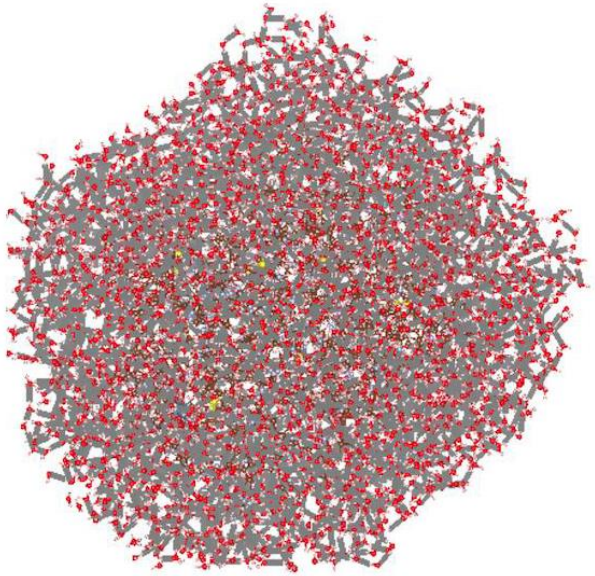
36 atoms



303 atoms



11,608 atoms



12,635 atoms

2024
October
arXiv:2410.09209

2024
November
arXiv:2411.09861

2025
December
arXiv:2512.17130

2026
April
arXiv:2605.01138

In collaboration with: RIKEN

2026
April
arXiv:2605.01138

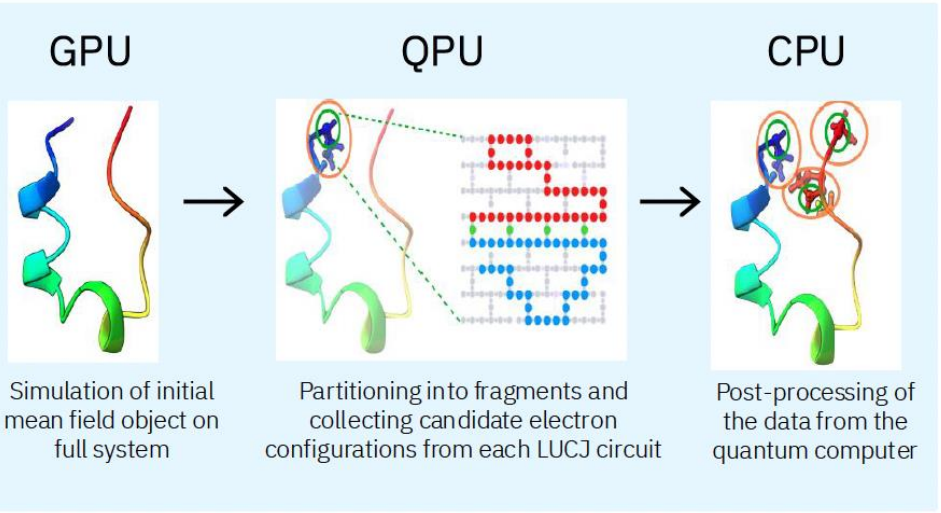
Pushing the scale of chemistry applications with quantum-cent supercomputing

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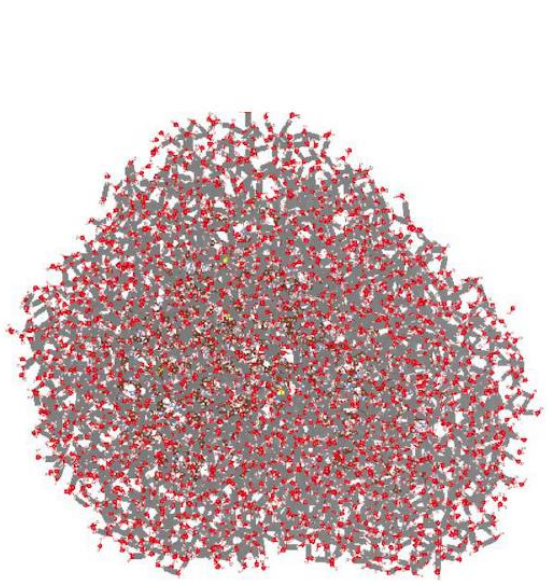
RIKEN Fugaku



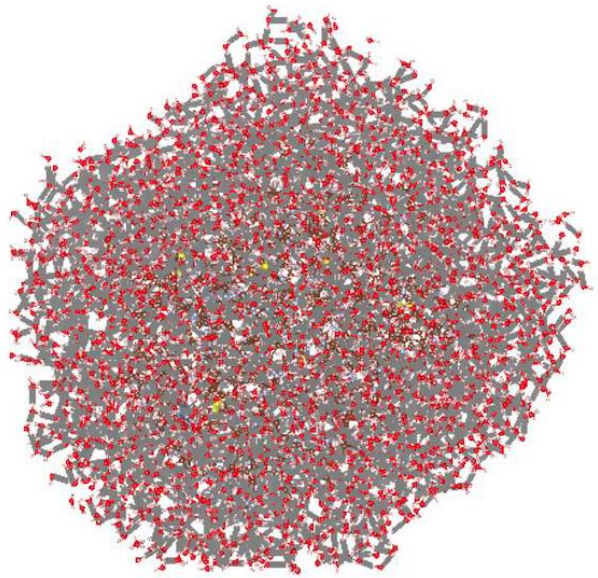


Cleveland Clinic, RIKEN, IBM named Gordon Bell Prize finalists

for new progress in automated quantum-HPC chemistry workflows.



11,608 atoms



12,635 atoms

2026
April
arXiv:2605.01138

In collaboration with:
RIKEN

2026
April
arXiv:2605.01138

Algorithms connect computational capabilities to applications

100+

Completed prototypes with industry clients

moderna

Predicting mRNA secondary structures with quantum optimization techniques

arXiv:2405.20328

Optimization

Cleveland Clinic

Simulating supramolecular interactions in pharma-relevant systems

Communications Physics **8**, 396 (2025)

Hamiltonian simulation

BOEING

Exploring material degradation caused by radicals

arXiv:2508.08229

Hamiltonian simulation

Vanguard

Portfolio optimization for fixed income assets

arXiv:2508.13557

Optimization

e·on

Decentralized energy system optimization

arXiv:2407.20802
arXiv:2412.07915
arXiv:2509.10657

Optimization QML

HSBC

Enhancing trade execution strategies for corporate bonds

arXiv:2509.17715

QML

Ansys

Simulating advection-diffusion and similar partial differential equations

arXiv:2508.16728

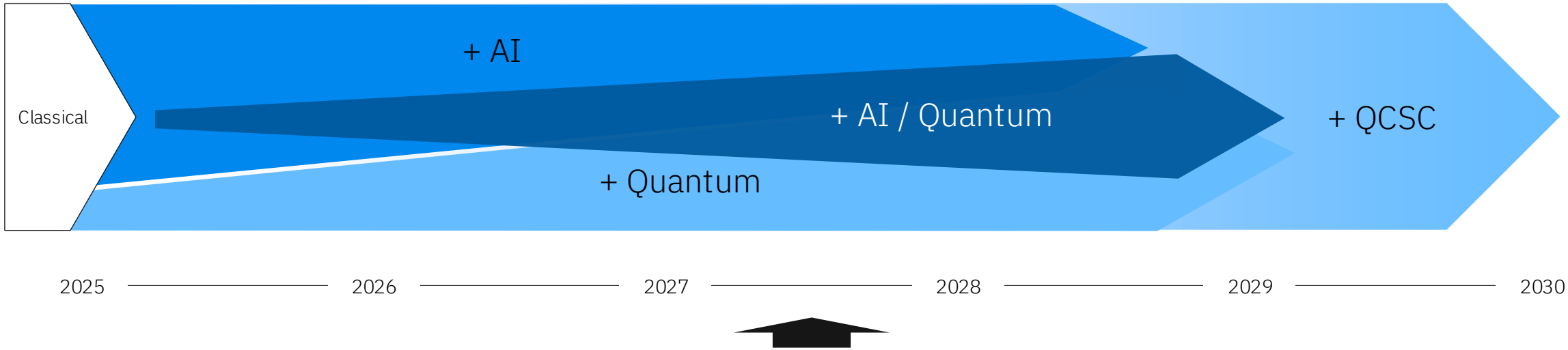
PDEs

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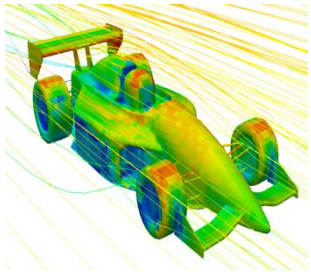
We are entering a new era of algorithm discovery

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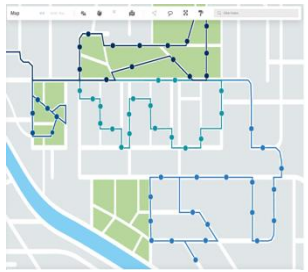
Tackling problems with algorithms that combine classical, AI & Quantum



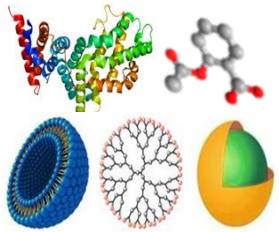
Fundamental problem classes in math and science



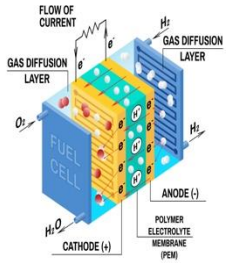
Differential equations and dynamical systems



Optimization and combinatorial problems



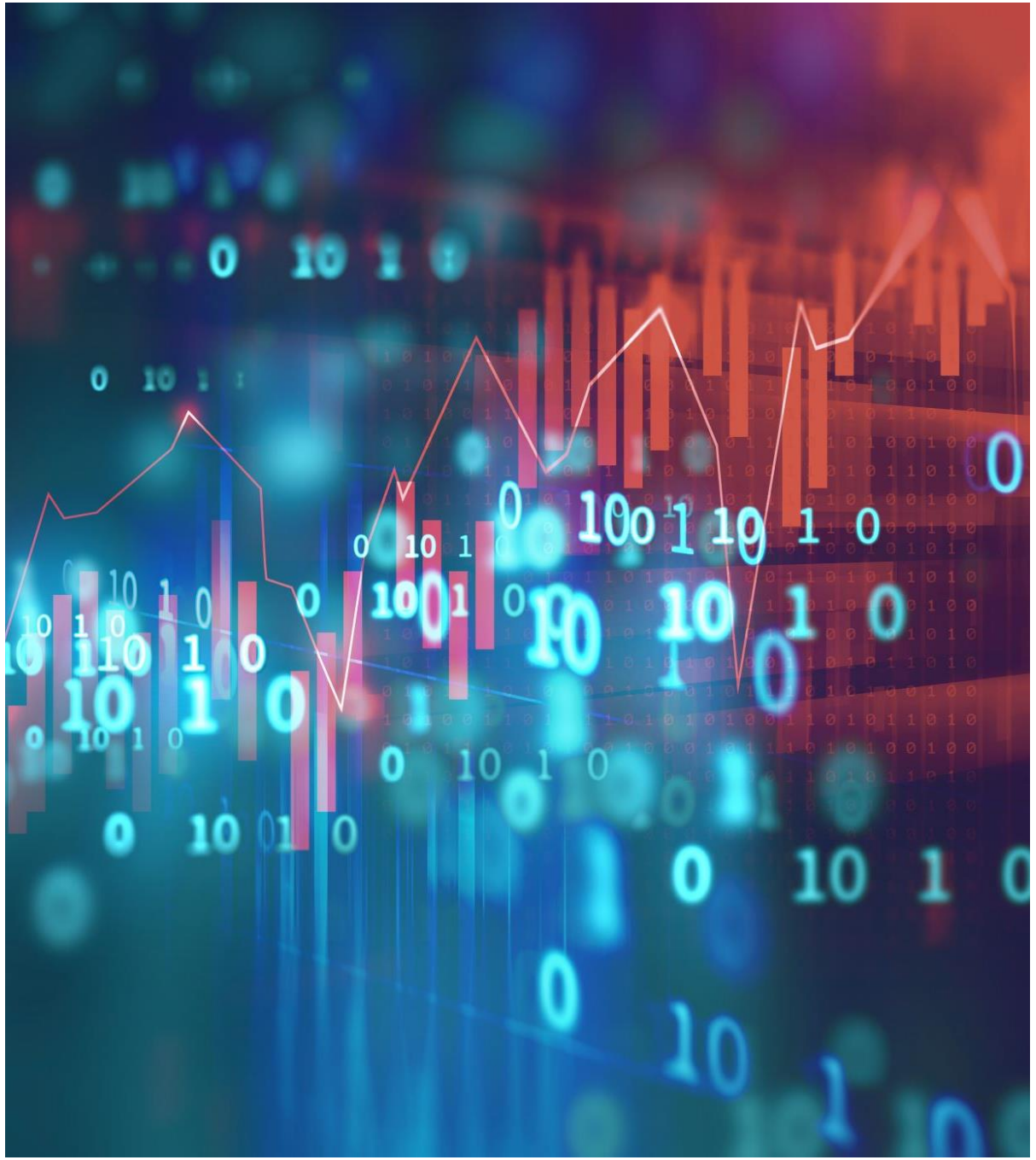
Linear algebra and eigenvalue problems



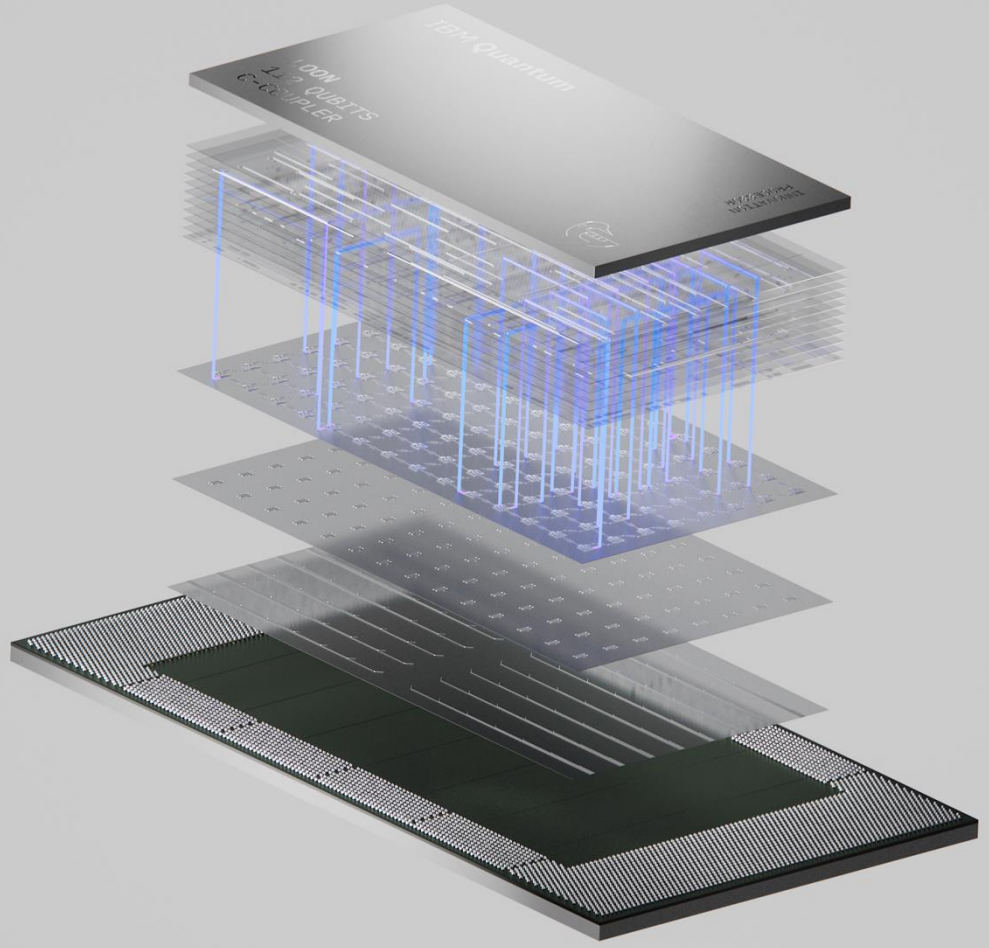
Probability, statistics, and stochastic processes

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Quantum Risk



Let’s create the future of computing together



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