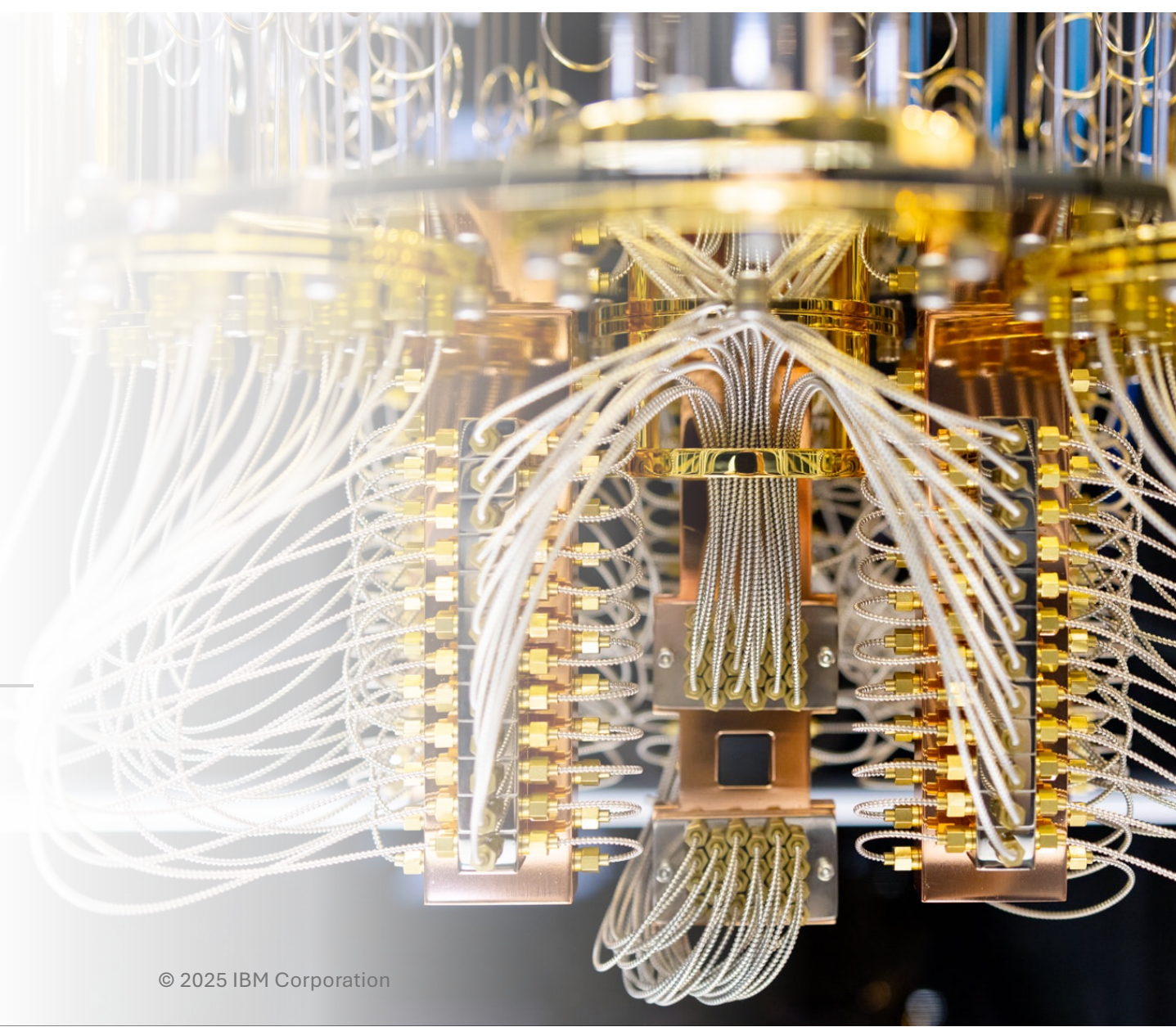




At the Intersection of Two Technological Revolutions: Quantum Computing and Artificial Intelligence

Arpad Pikethy
Country Leader
IBM Hungary



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Reinventing how work gets done |
+AI to AI+

IBM is actively
engaging with
enterprise clients
across a broad
set of business
domains

*Client results and
analyst studies*

Customer-facing functions and experiences	HR, Finance, and Supply chain functions	IT development and operations	Core business operations
Customer service Empower customers to find solutions with easy, compelling experiences 90% customer inquiries handled by an AI assistant	HR automation Reduce manual work and automate recruiting, sourcing and nurturing job candidates 40% improvement in HR productivity	App modernization, migration Generate code, tune code generation response in real time 60% software development content auto generated by AI	Threat management Reduce incident response times from hours to minutes or seconds Contain potential threats 8x faster
Marketing Increase personalization, improve efficiency across the content supply chain Reduce derivative content creation spend	Supply chain Automate source to pay processes, reduce resource needs and improve cycle times Reduce cost per invoice by up to 50%	IT automation Reduce automation development, identify deployment issues, avoiding incidents, optimize application demand to supply Reduce mean time to repair (MTTR) by 50%+	Asset management Optimize critical asset performance and operations while delivering sustainable outcomes Reduce unplanned downtime by 43%
Content creation Ex. Enhance digital sports viewing with auto-generated spoken AI commentary Scale live viewing experiences cost effectively	Planning and analysis Make smarter decisions, focus on higher value tasks with automated workflows and AI Process planning data up to 80% faster	AIOps Assure continuous, cost- effective performance and connectivity across applications Reduce application support tickets by 70%	Product development Ex. Expedite drug discovery by inferring structure with AI from simple molecular representations Faster and less expensive drug discovery
Knowledge worker Enable higher value work, improve decision making, and increase productivity Reduce 90% of text reading and analysis work	Regulatory compliance Support compliance based on requirements / risks, proactively respond to regulatory changes Reduce time spent responding to issues	Data platform engineering Redesign the approach for data integration using generative AI Reduce data integration time by 30%+	Environmental intelligence Provide intelligence to proactively plan and manage impact of severe weather and climate Increase manufacturing output by 25%

Quantum AI for complex data structure use cases

Until Now

Different Quantum AI heuristics methods:
QSVM, QNN, Quantum Gen AI, etc.

Quantum AI could add value:

*Find new patterns
with less data
in complex data structure
with better trainability*

Quantum AI a complementary tool to AI

Few potential industry use cases identified and explored with real-world data

What's next?

Identify more value-added use cases for QML

More experimentation with real world data in real world context

Scale experimentation to utility prototype

Quantum AI business workflow redefined

Think about real world applicability & constraints

Continue to find better QML algorithms through theory & experimentation with real HW

Computationally complex problems exist across almost every industry.

Bringing **useful quantum computing** to the world

Banking

- Fraud monitoring
- Portfolio optimization
- Risk simulation
- Customer analytics
- Time series forecasting

Automotive

- Battery material design
- Material design
- Mobility as a Service
- Quality control
- Self-driving and ADAS
- Production optimization

Chemicals

- Sustainable products
- Low-carbon manufacturing
- Resilient supply chains
- Process optimization
- Asset health

Life sciences

- Efficient drug research and development
- Clinical trials
- Tractable protein folding
- Cell-centric therapeutics
- mRNA

Healthcare

- Accelerated diagnoses
- Personalized interventions
- Adherence to drugs
- Biomarkers
- Image processing

Logistics

- Global logistics optimization
- Disruption management
- Routing optimization
- Predictive maintenance
- Forecasting

Public services

- Security/safety
- Multimodal transport
- City resource planning
- Disaster management
- Fraud detection in tax and social

Insurance

- Catastrophe modeling
- Precise customer profiling
- Efficient risk management
- Optimized pricing of premiums

Electronics

- Faster product design
- Circuit defect identification
- Process optimization
- Production optimization
- Quality control

Airlines

- Forecasting and revenue
- Irregular operations
- Network planning
- Safety and maintenance
- Hyper-personalization

Energy and utilities

- Energy trading
- Optimization of energy grid
- Renewables system design
- Energy forecasting
- Hyper-personalization
- Asset health

Aerospace

- Material discovery
- Aircraft design
- Asset health
- Corrosion and material interaction
- Fuel efficiency

Oil and gas

- Emissions reduction
- Reservoir simulation
- Virtual flow meters
- Subsurface modeling
- Failure prediction

Telecom

- Network optimization
- Network anomaly detection
- Contextual customer segmentation
- Cybersecurity network

Quantum AI could be leveraged in all industries

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Advancing materials simulation for high-temperature superconductors

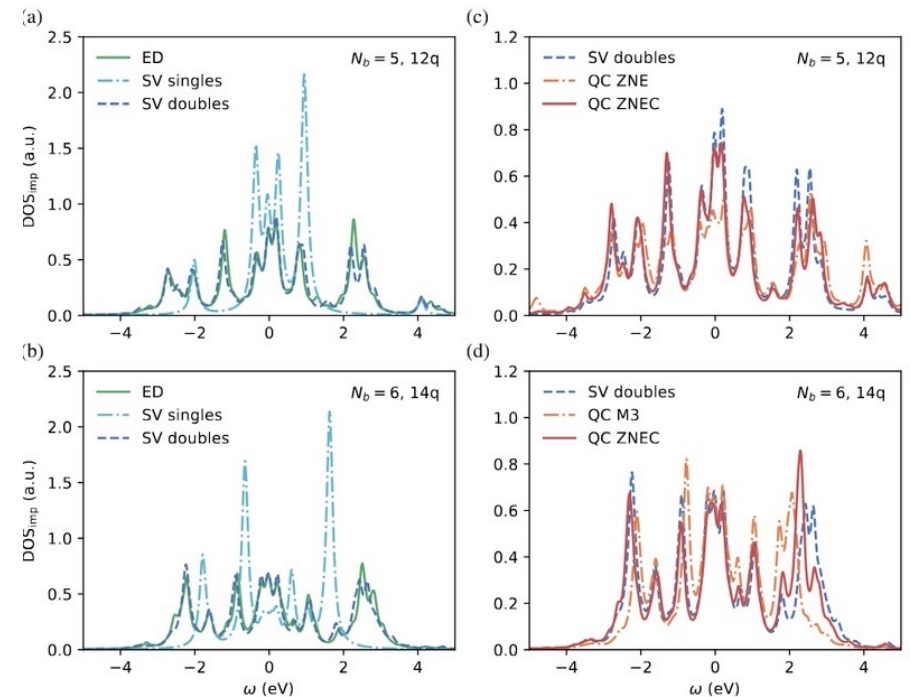
Simulation

Bosch partnered with IBM to develop a [scalable hybrid quantum-classical workflow](#) for simulating the energy distribution of electrons in real materials, starting with $\text{Ca}_2\text{CuO}_2\text{Cl}_2$, a parent compound for high-temperature superconductors with highly correlated structure.

Using the IBM Quantum Heron processor, they ran the [largest simulation at the time for a real monocrystalline material on a quantum computer](#), the validity of which was proven by agreement with experimental data and best-in-class classical simulations.

“The combination of the new Heron chip with the new error mitigation scheme developed by Bosch gave us beautiful results, with excellent agreement of the mobility of electrons between the quantum calculation and experimental data.”

Thomas Eckl
Chief Expert, Bosch Research



■ These figures show the calculation of a materials science quantity-of-interest called the density-of-states. The top row and bottom row represent 12 and 14-qubit experiments, respectively. The left column represents the brute-force answer with a solid line, and the technique discussed in the paper run on a simulator with dotted lines. The right column compares the simulator results with real hardware performance on `ibm_torino` with error mitigation applied.

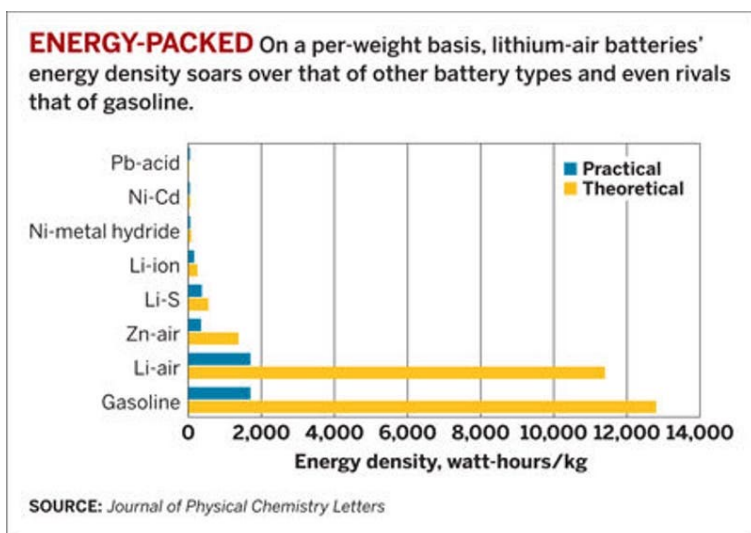
Read the paper: [arXiv:2404.09527](#)

Mitsubishi Chemical

Lithium-air battery chemistry

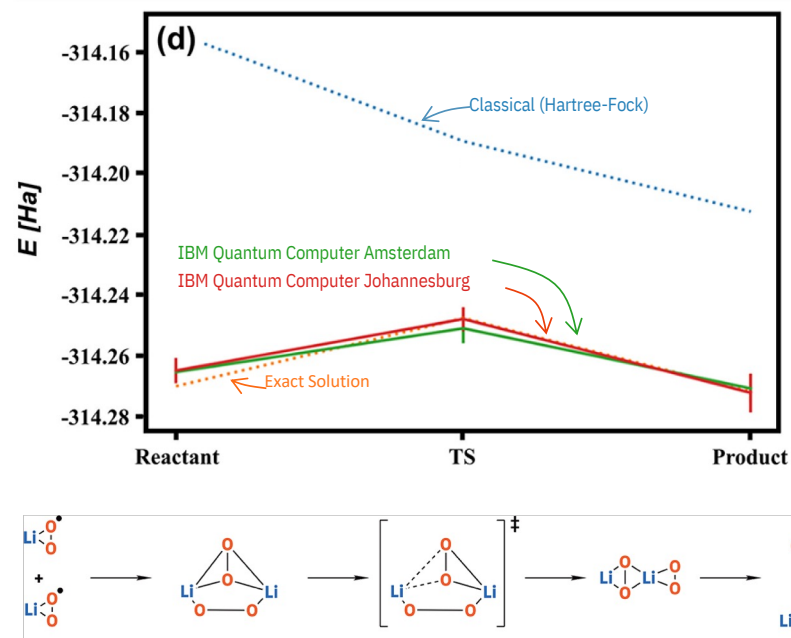
Simulation

Lithium-air batteries have demonstrated energy densities 5x higher than lithium-ion batteries and theoretical energy densities comparable to gasoline yet face many challenges in chemistry industrialization.



Source: The Journal of Physical Chemistry A 125.9 (2021): 1827-1836.

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Mitsubishi Chemical and IBM investigated the rearrangement of the lithium superoxide dimer, which requires an accurate description of bond breaking and formation through a transition state. The team demonstrated proof of principle of a complete reaction with a quantum computer (state-of-the-art at the time).



Predicting mRNA secondary structures with quantum optimization techniques

Optimization

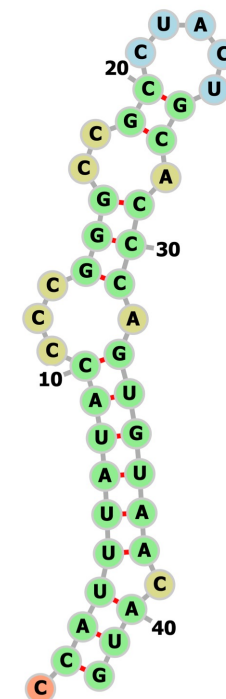
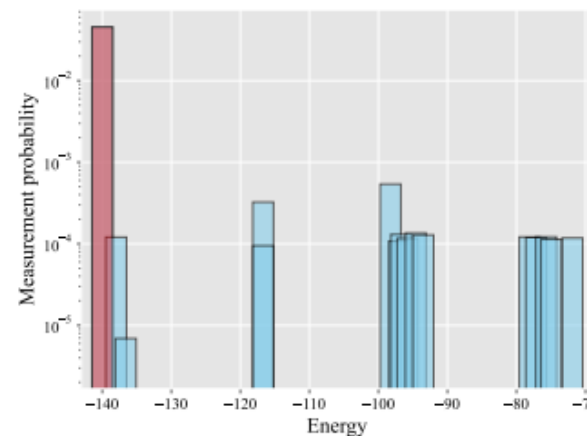
Moderna partnered with IBM to develop quantum computing algorithms for [predicting mRNA secondary structures at greater scale and accuracy](#), with the goal of unveiling novel and more diverse mRNA therapies.

Running the CVaR-VQA algorithm on IBM Quantum Eagle and IBM Quantum Heron processors yielded [accurate insights into folding mechanisms for mRNA sequences of up to 42 nucleotides](#) (mapped to 10–80 qubits) and their associated energy states that match the results of the classical solver CPLEX.

“Our world is a quantum mechanical world, and so when we try to simplify things in a deterministic world, we’re not going to really be able to emulate that complexity.”

Wade Davis

Senior Vice President, Digital for Business, Moderna



- These figures show (a) the measurement probability of sampled bitstrings plotted against bitstring energies for the 80-qubit problem, where the red bar indicates the probability corresponding to the lowest energy bitstring; and (b) the optimal folded structure of the 42-nucleotide, 80-qubit mRNA sequence based on the corresponding lowest energy bitstring found by the hardware run.

Read the paper: [arXiv:2405.20328](#) | Explore the demo: [ibm.biz/BdGAB6](#)

ExxonMobil

Routing optimization

In 2021, more than 500 liquified natural gas (LNG) ships were used to transport critical fuel supplies across the oceans. Together, they make thousands of journeys per year to destination ports where the LNG is deployed to power critical infrastructure.

Finding optimal routes for a fleet of such ships can be a mind-bendingly complex optimization problem.

<https://www.ibm.com/case-studies/exxonmobil/>
IEEE Trans Quantum Engineering, vol. 2, p. 1

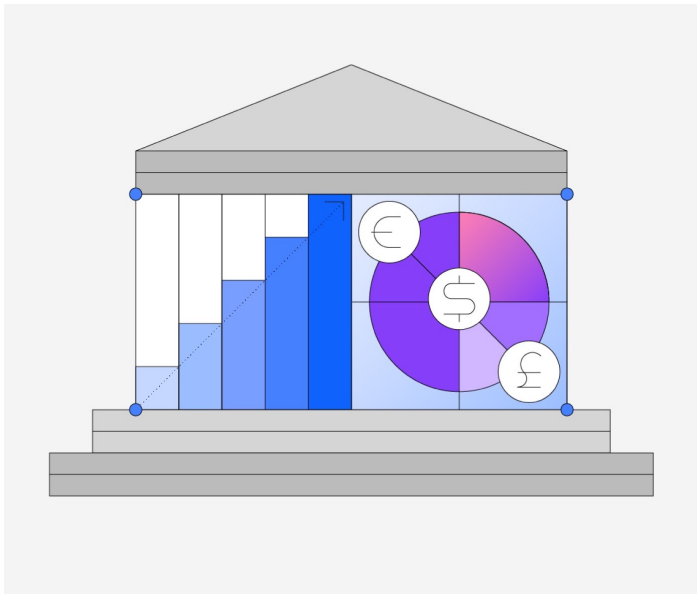


Quantum computers take a new approach to addressing this sort of complexity, with the potential to find solutions that classical supercomputers alone cannot handle. Industry leaders like ExxonMobil are getting involved now to explore how blending classical and quantum computing techniques might solve big, complex, pressing global challenges.

Voice of our first adopters

HSBC

- Pricing and portfolio optimization
- Sustainability
- Fraud management
- Risk management



“This technology has the potential to transform how we run areas of the bank by addressing challenges which classical computers may never be able to solve, alone. Our work with IBM, a leading provider of quantum computing, is essential to harnessing this potentially game-changing technology for financial services.”

Colin Bell, CEO of HSBC Bank and HSBC Europe

Exploring business value with quantum and AI



LONDON, Sept 25 (Reuters) - Europe's biggest bank HSBC said on Thursday that a trial use of quantum computers to aid bond trading had produced promising results, in a rare example of a major finance company finding early benefits from the emerging technology.

HSBC said its quantum computing pilot - run with technology firm IBM had delivered a **34%** improvement in predicting how likely a bond trade would be filled at a quoted price, giving it a competitive edge compared to normal computing.

Ecosystem

IBM Quantum Platform hosts the strongest ecosystem advancing quantum computing

The IBM Quantum Network has 275+ members

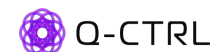
Industry members 50+

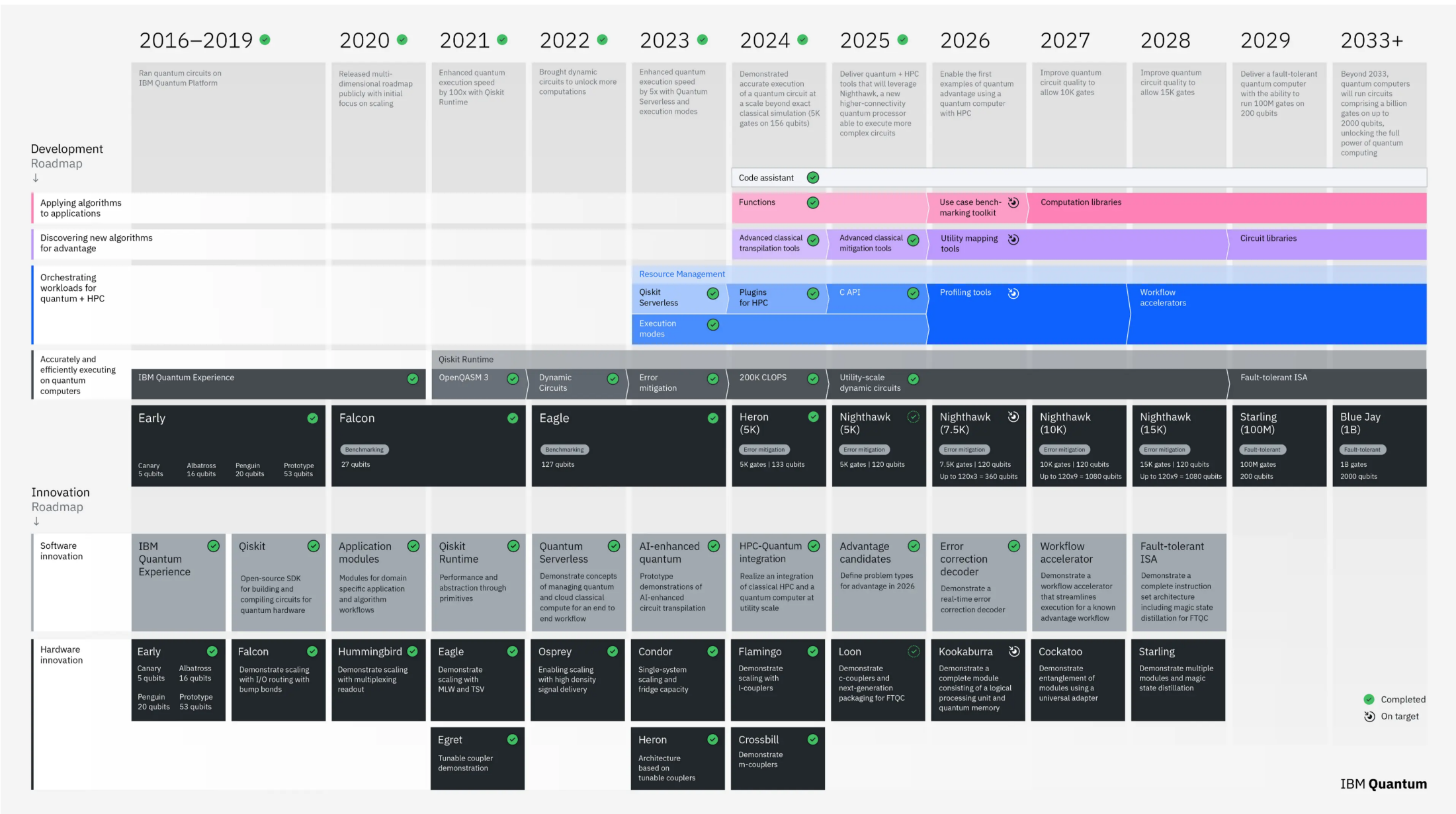
Commercial partners and startups 55+

Academic and research institutions 170+

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Scaling circuit size through the error correction transition

As we focus on performance, our roadmap highlights a more important metric than qubit count alone: The gate count, which measures the circuit's complexity. We calculate it by multiplying the width—the number of qubits—by the depth, the number of operations you can run on a qubit before it decoheres.

Error mitigation will allow us to increase circuit complexity for the next four years. The tradeoff is that you must run more circuits iteratively and perform classical post processing.

In 2029, we introduce error correction. The width of these circuits—the number of qubits in your calculation—is essentially the same, but you can now run much deeper circuits — those with more operations. The tradeoff is it requires much more physical hardware.

With error correction implemented, we can then start scaling to circuits that are both deeper and wider as we move from Starling to Blue Jay.

2027

Flamingo
(10K)

Error mitigation

10k gates
156 qubits

Quantum modular

Up to $156 \times 7 =$
1092 qubits



2028

Flamingo
(15K)

Error mitigation

15k gates
156 qubits

Quantum modular

Up to $156 \times 7 =$
1092 qubits



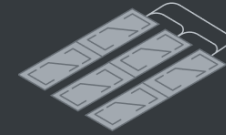
2029

Starling
(100M)

Error correction

100M gates
200 qubits

Error corrected
modularity



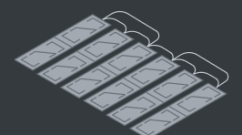
2033+

Blue Jay
(1B)

Error correction

1B gates
2000 qubits

Error corrected
modularity



QSCP in Hungary

To realize Quantum Advantage,
we need a dedicated community
of industries, researchers, and
practitioners to activate the use
of quantum algorithms.

Quantumtechnology and Supercomputer Platform QSCP

Our vision is to unite the leading minds of research, industry, academia, and the public sector, forging an ecosystem where the combined power of quantum computing, artificial intelligence, and high-performance computing unlocks unprecedented possibilities and drives transformative progress for the Hungarian economy and society



QSCP Future Goal / Vision

