

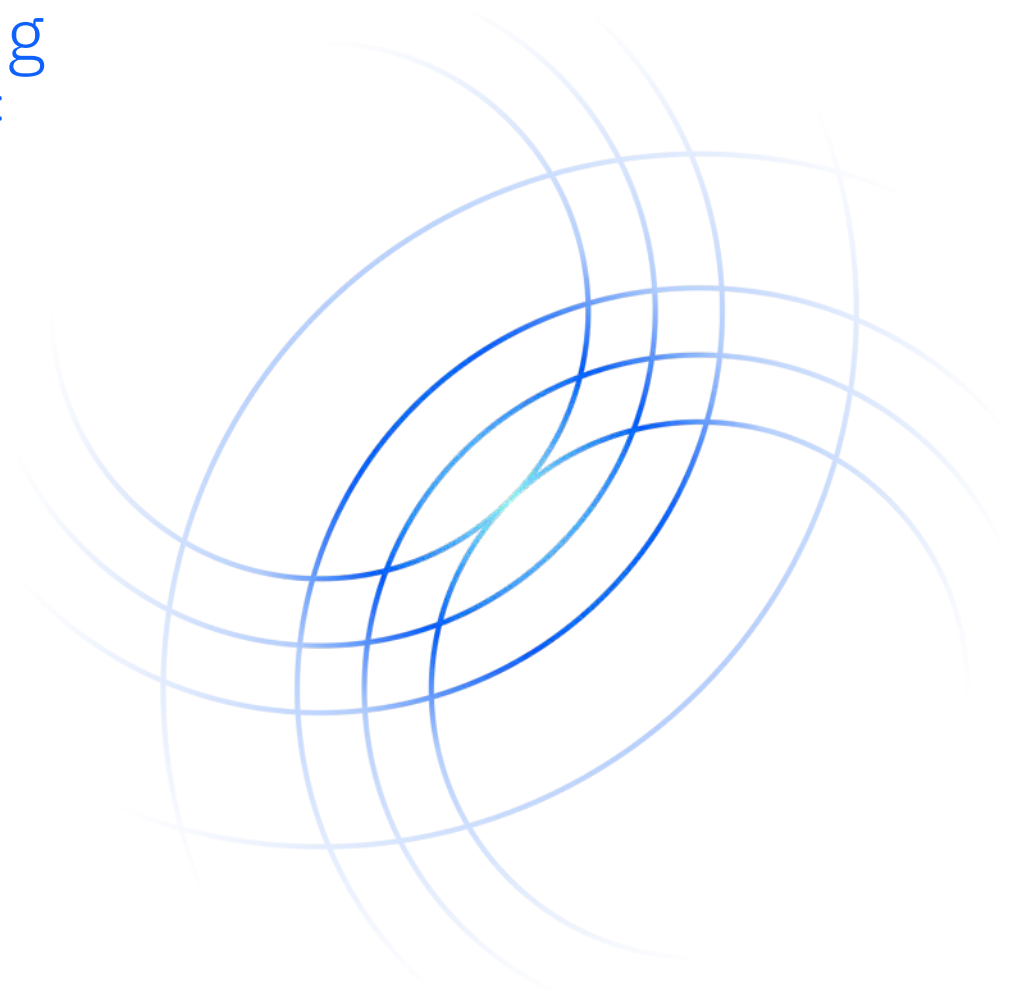
# IBM Quantum Computing

Towards weather/climate forecasting:  
Prospects for large scale modeling,  
optimization and computation

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Kevin Roche

IBM Quantum Ambassador





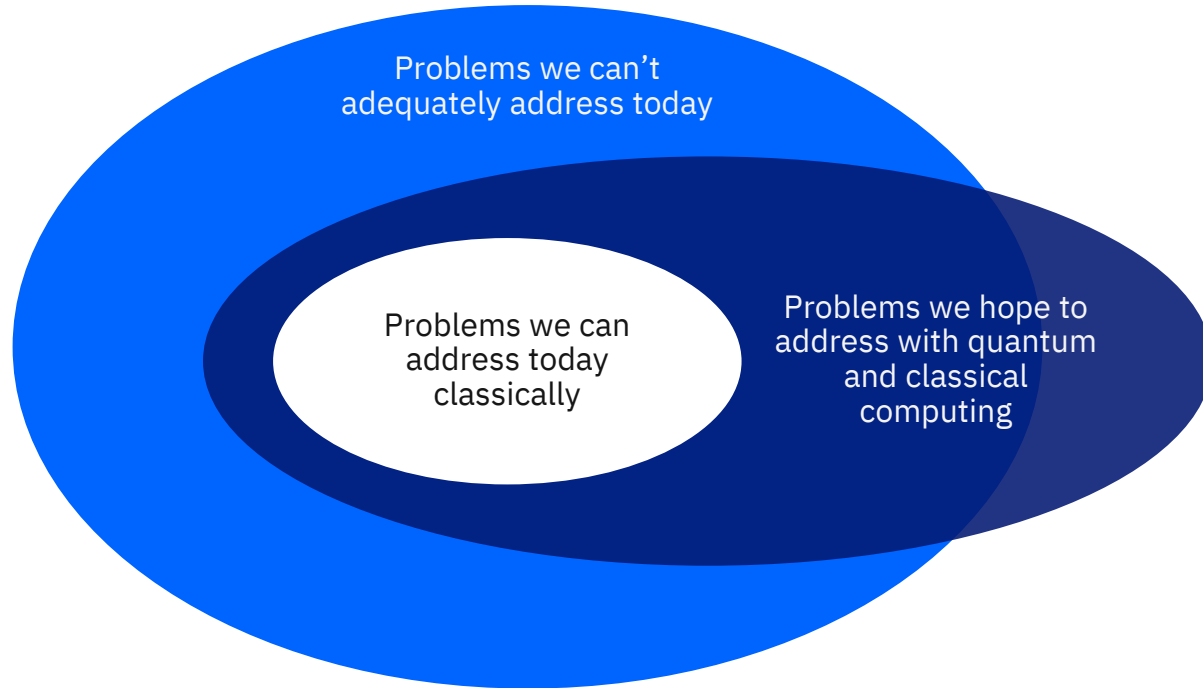
Our mission

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Bring useful quantum  
computing to the world

Make the world  
quantum safe

# Why quantum?



Despite how sophisticated digital “classical ” computing has become, there are many scientific and business problems for which we’ve barely scratched the surface.

# Quantum applications span three general areas

## Simulating Quantum Systems

- Improved battery materials
- Manufacturing defect identification
- Semiconductor materials
- Chemical property prediction
- Drug Discovery
- Protein Structure Predictions
- Disease Risk Predictions

- Accelerated Diagnosis
- Genomic Analysis
- Chemical product design
- Catalyst discovery
- Chemical process optimization
- High energy physics classification
- Transaction classification
- Product recommendation

## Artificial Intelligence

- Fraud detection
- Risk analysis
- Options pricing
- Derivatives Pricing
- Investment Risk Analysis
- Portfolio Management
- Transaction Settlement
- Finance Offer Recommender
- Credit/Asset Scoring
- Airline Scheduling

## Optimization / Monte Carlo

- Irregular Operations
- Network Optimization
- Product Portfolio Optimization
- Process Planning
- Quality Control
- Vehicle Routing
- Raw materials shipping
- Refining Processes
- Seismic imaging
- Disruption Management

- Freight Forecasting
- Irregular Operations
- Fabrication Optimization
- Manufacturing Supply Chain
- Fluid Dynamics

and many more ...

# Building a Quantum Computing *Industry*

03

## Industry Adoption

- ↳ Direct client interactions
- ↳ Scaling solutions with partner engagements

04

## Application Services

- ↳ Access compute resellers
- ↳ Software providers
- ↳ Application integration

05

## Quantum Safe

- ↳ Direct client interactions
  - ↳ Prepare & Discover
  - ↳ Assess & Plan Transformation
  - ↳ Transform & Ongoing Observability

02

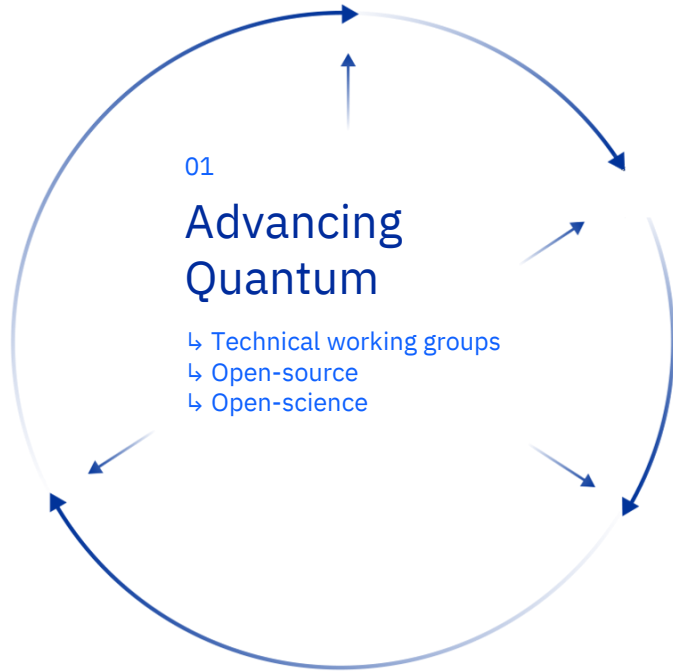
## Quantum Innovation Centers

- ↳ Access to leading-edge quantum compute services
- ↳ Research and development
- ↳ Education and workforce development
- ↳ Economic development

01

## Advancing Quantum

- ↳ Technical working groups
- ↳ Open-source
- ↳ Open-science



# Education and Workforce enablement

## 250+

Fortune 500 companies, universities, laboratories and startups in the Quantum Network

<https://www.ibm.com/quantum/network>

## \$100M

Invested over the last 5 years supporting open quantum computing education

## 500+

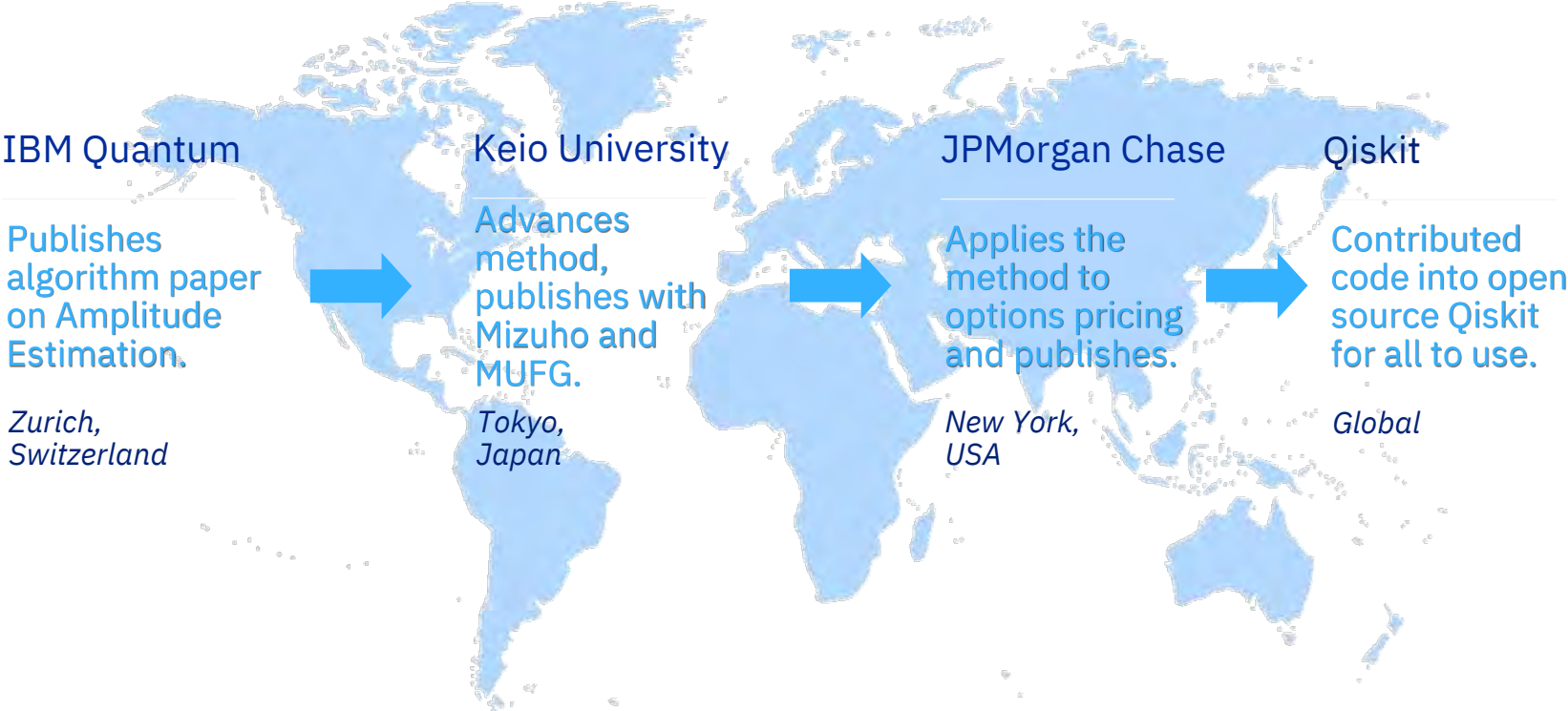
Courses being taught with IBM Quantum tools and resources

## 6M+


Learners reached across all educational platforms







# A snapshot of global collaboration within the IBM Quantum Network



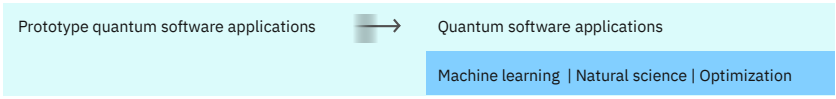
# Development Roadmap

Executed by IBM   
On target 

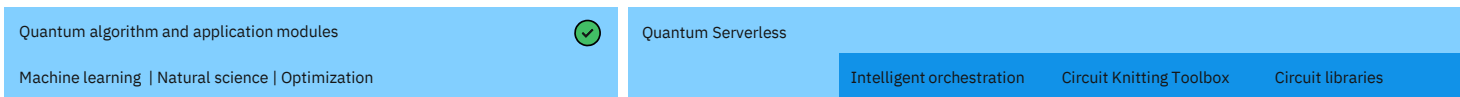
IBM Quantum

2019 	2020 	2021 	2022 	2023	2024	2025	Beyond 2026
Run quantum circuits on the IBM cloud	Demonstrate and prototype quantum algorithms and applications	Run quantum programs 100x faster with Qiskit Runtime	Bring dynamic circuits to Qiskit Runtime to unlock more computations	Enhancing applications with elastic computing and parallelization of Qiskit Runtime	Improve accuracy of Qiskit Runtime with scalable error mitigation	Scale quantum applications with circuit knitting toolbox controlling Qiskit Runtime	Increase accuracy and speed of quantum workflows with integration of error correction into Qiskit Runtime

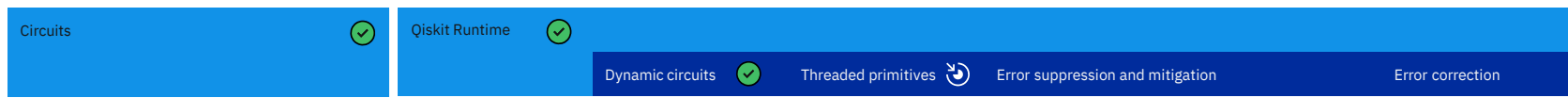
Model Developers



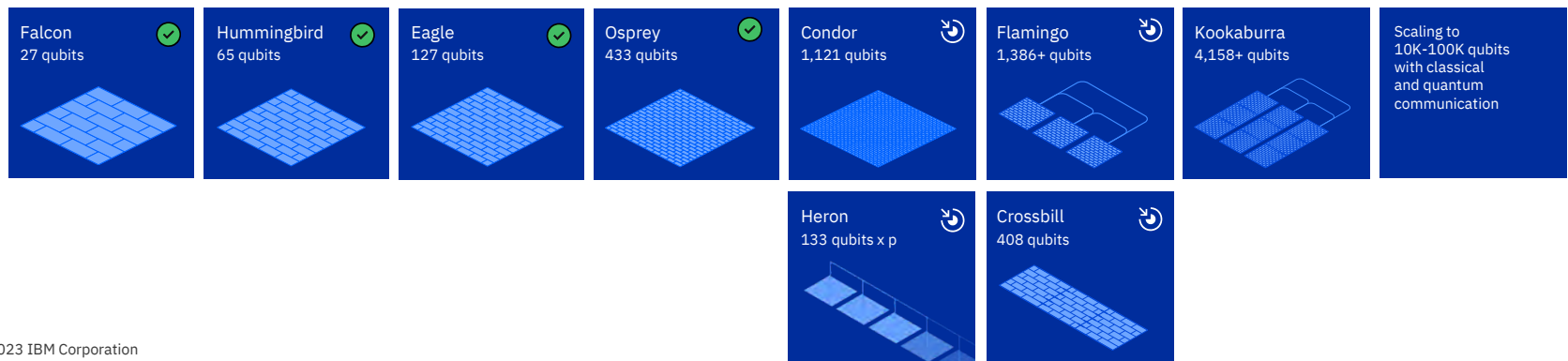
Algorithm Developers



Kernel Developers



System Modularity



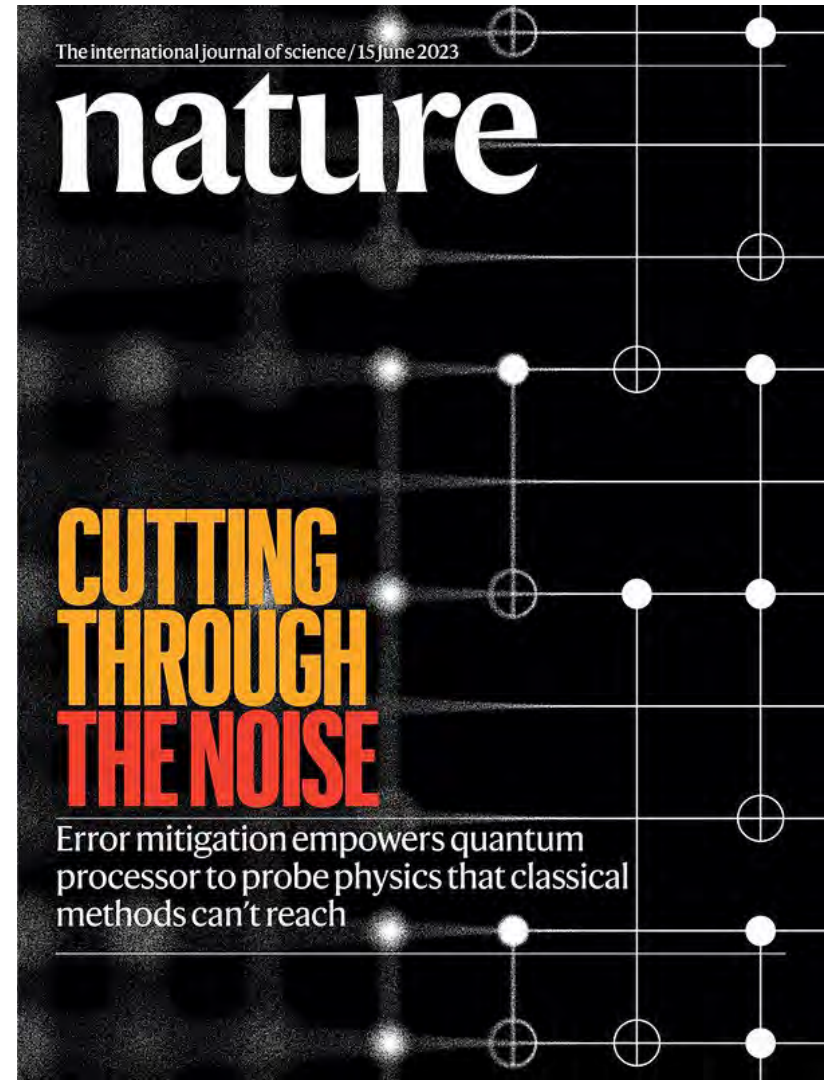


# Nature 2023: Quantum Utility

A noisy quantum computer is able to produce accurate expectation values in regimes beyond brute force computation

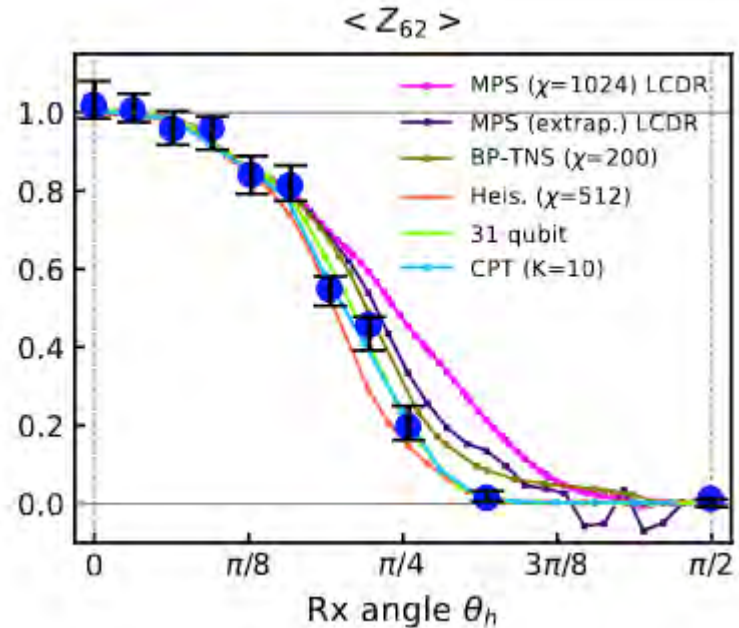
This serves as evidence for the utility of quantum computing before fault tolerance

<https://www.nature.com/articles/s41586-023-06096-3>



# Back and forth between classical and quantum

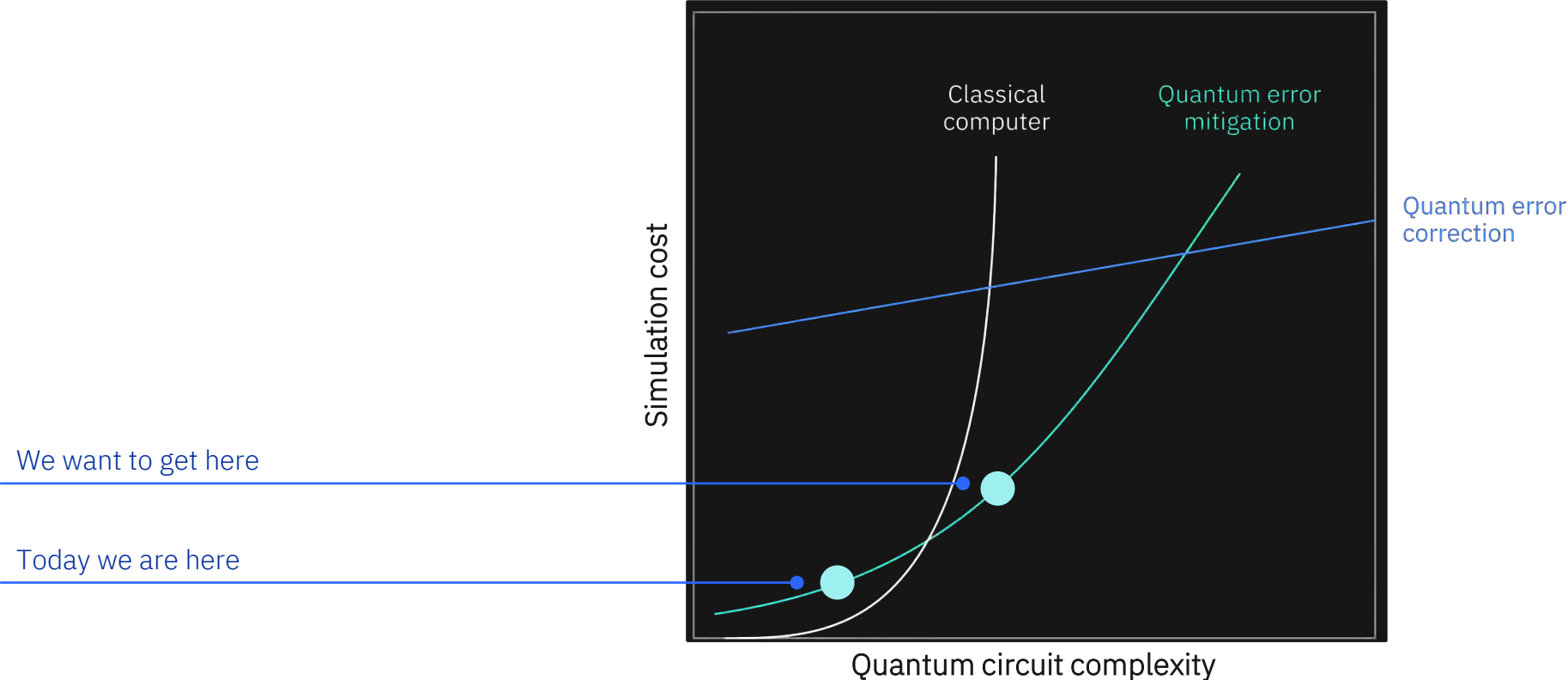
- Flurry of activity to simulate the implemented circuits since publication
- Four new classical methods differ by  $\sim 20\%$  amongst themselves near  $\theta_h \sim \pi/4$ , an amount largely within the spread of the ZNE error bars
- Utility-scale experiments will keep motivating new extensions to state-of-the-art classical methods



<https://arxiv.org/abs/2306.17839>

*Quantum utility* refers to our increasing ability to get accurate results from quantum computers and entering the era of quantum utility marks the transition of this technology into a tool for scientific exploration

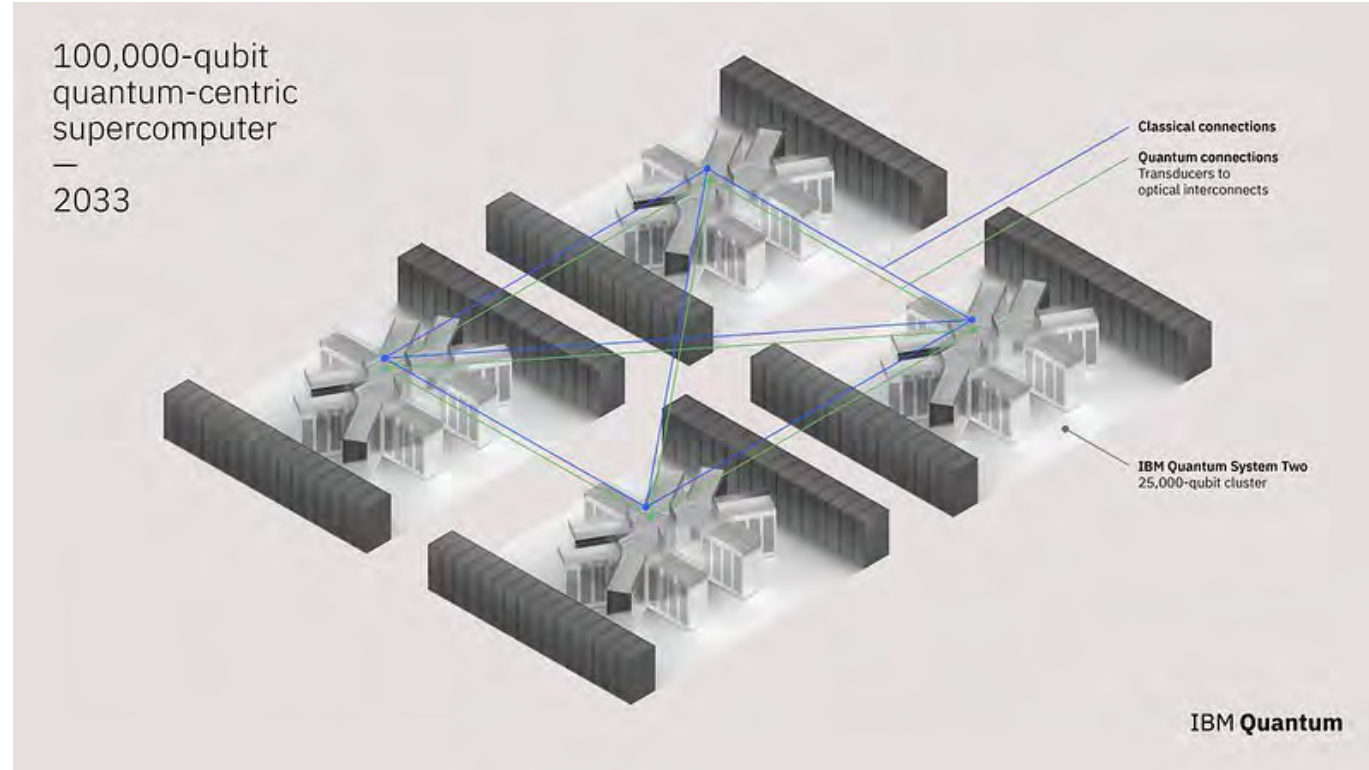
# Noise-free Estimates of Observables



# IBM launches partnership with the University of Chicago and the University of Tokyo to develop a 100,000-qubit Quantum-Centric Supercomputer

The 10-year, \$100 million initiative is a global collaboration and an activation of talent and resources across industries and research institutions is being initiated.

By partnering with the University of Chicago, the University of Tokyo, and IBM's broader global ecosystem, IBM will work over the next decade to advance the underlying technologies for this system, as well as to design and build the necessary components at scale [\[1\]](#).



## Maritime Routing's Mind-Boggling Math

In 2021 more than 500 LNG (liquified natural gas) ships are 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.



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

# IBM Quantum Computing

- News & Blog
- Research
- Products
- Opportunities
- Case Studies
- Education
- Access Plans



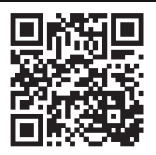
[ibm.com/quantum](https://ibm.com/quantum)

## Tools

Access IBM Quantum Systems via

- Quantum Composer
- Quantum Lab

[quantum-computing.ibm.com](https://quantum-computing.ibm.com)



# IBM Quantum Safe

Securing the world's digital infrastructure for the era of quantum computing



[ibm.com/quantum/quantum-safe](https://ibm.com/quantum/quantum-safe)

## Report:

Security in the quantum computing era



(IBM Institute for Business Value)



Open Source Quantum Development



Qiskit textbook

- Online learning
- Qiskit Community

[qiskit.org](https://qiskit.org)

Qiskit YouTube Channel



[youtube.com/Qiskit](https://youtube.com/Qiskit)

# Contact IBM Quantum



Fill out our online form so an IBM Quantum representative may follow up with you.

