ASPIRE

BEYOND THE BUBBLE

WORLD STAGE

QUANTUM COMPUTING

WHY IT WILL CHANGE EVERYTHING

Steve Suarez
HorizonX

Sławek Kumka
IBM Software Lab

#1

AI is transforming the field of IT and programming specifically, but it is not poised to replace human programmers entirely.
They will evolve, with AI serving as a powerful tool that enhances human capabilities.

#2

AI will lead to a shift in the types of IT jobs available, rather than a decrease in jobs. IT jobs will evolve to focus more on AI supervision, training, and collaboration. It will include soft skills as well.

#3

Generative AI won't replace people, but people who use generative AI will replace people who don't.

#1

AI is everywhere.

#2

AI is boring.
Everyone has it.

#3

If not only Artificial Intelligence, then WHAT....?

We have entered the era of Quantum.

What is a quantum computer?

$\hbar$

Simulating Physics with Computers

Richard P. Feynman

Department of Physics, California Institute of Technology, Pasadena, California 91107

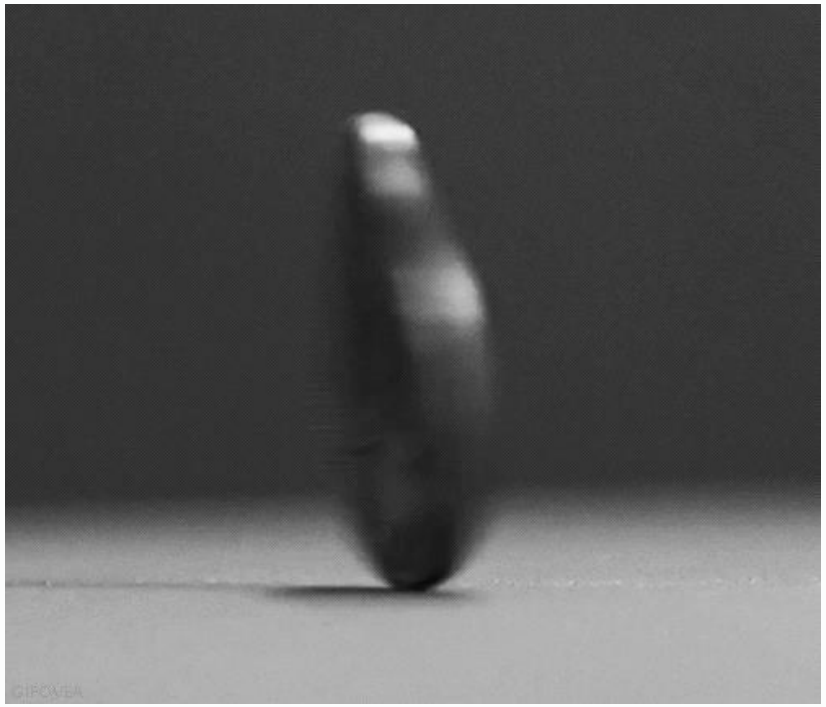
Received May 7, 1981

Bit

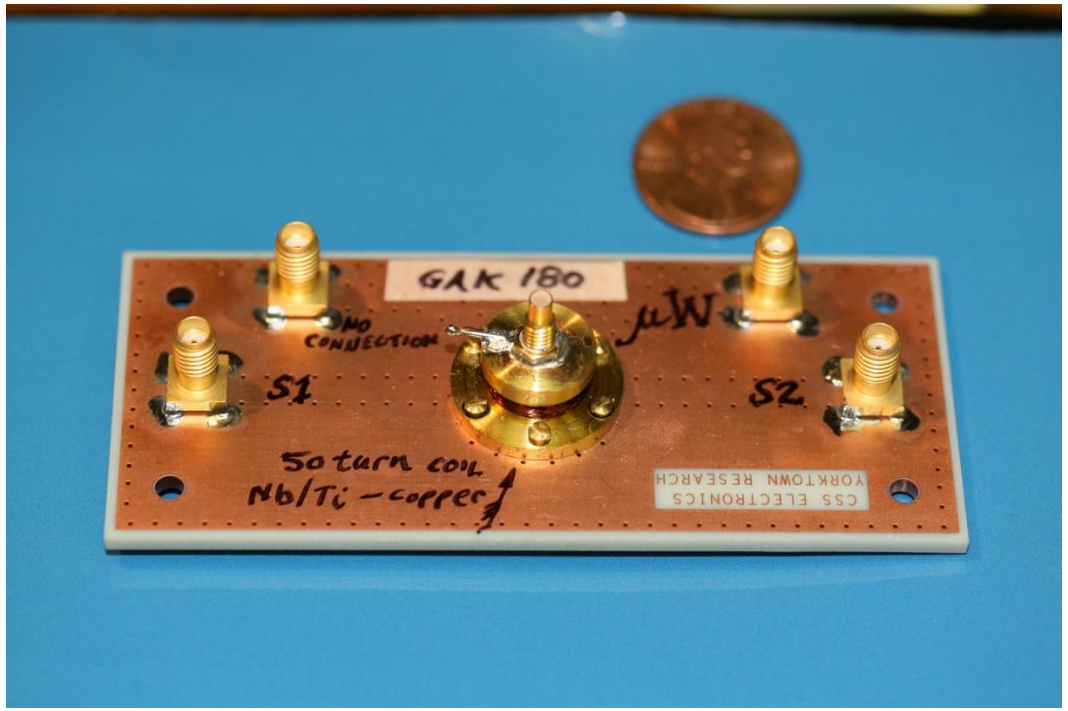
OR

0 1

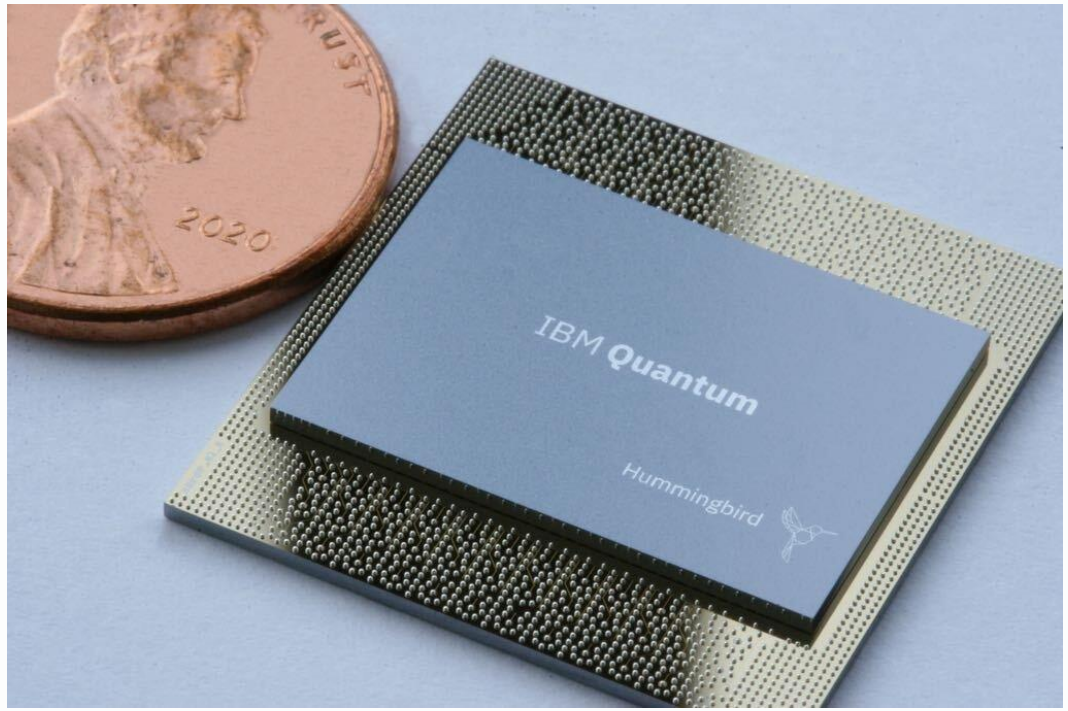
Quantum Bit (Qubit)



2010



2020



2019
Falcon
27 Qubits

2021
Eagle
127 Qubits

2022
Osprey
433 Qubits

Condor

1121 qubits


POK - 8 - 8

IBM Quantum System One

- **100+ qubits**
- The world's largest fleet of quantum computing systems, all with more than 100 qubits

- Advanced processors offering error per layered gate (EPLG) as low as 0.8% and CLOPS (a measure of how quickly our processors run quantum volume circuits in a series) as high as 5K

- **Enhanced connectivity**
- New coupling technologies to forge more connections between qubits

- **Powerful processors**
- Tunable couplers between fixed-frequency qubits dramatically reduce noise

See all available system metrics: quantum.ibm.com/services/resources?tab=systems

Learn more about performance metrics: www.ibm.com/quantum/blog/quantum-metric-layer-fidelity

Heron

133

qubits

IBM Quantum System Two

Applications

Simulating Quantum Systems

Artificial Intelligence

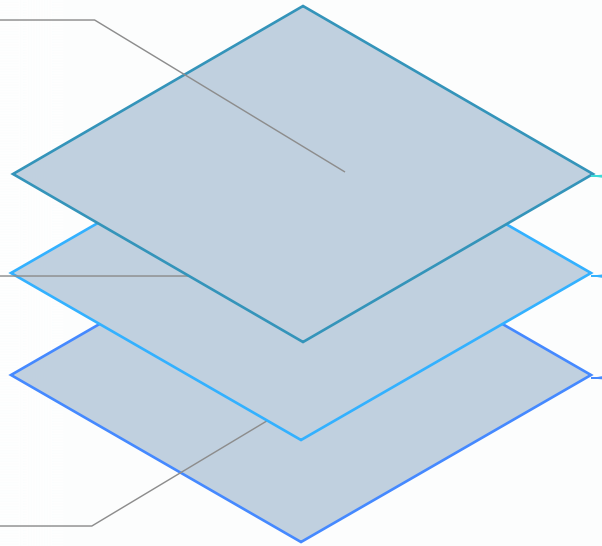
Optimization

Quantum computing is expected to have impact across industries

Simulating nature

Mathematics and processing data with complex structure i.e. (Machine Learning)

Search and optimization



Aerospace & Automotive	Customer Experience Materials Design Structural Design Optimization And more
Financial Services	Fraud Detection Derivatives/options pricing Portfolio optimization Risk analysis And more
High Tech	Seismic Imaging Catalysts Supply chain planning Manufacturing scheduling And more
Energy, Environment, Utilities	Portfolio optimization Grid optimization Risk Analysis and Options Pricing Battery Design And more
Health Care & Life Sciences	Disease risk prediction Drug discovery and design Protein folding predictions And more

These computationally complex problems exist across almost every industry.

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
- Call-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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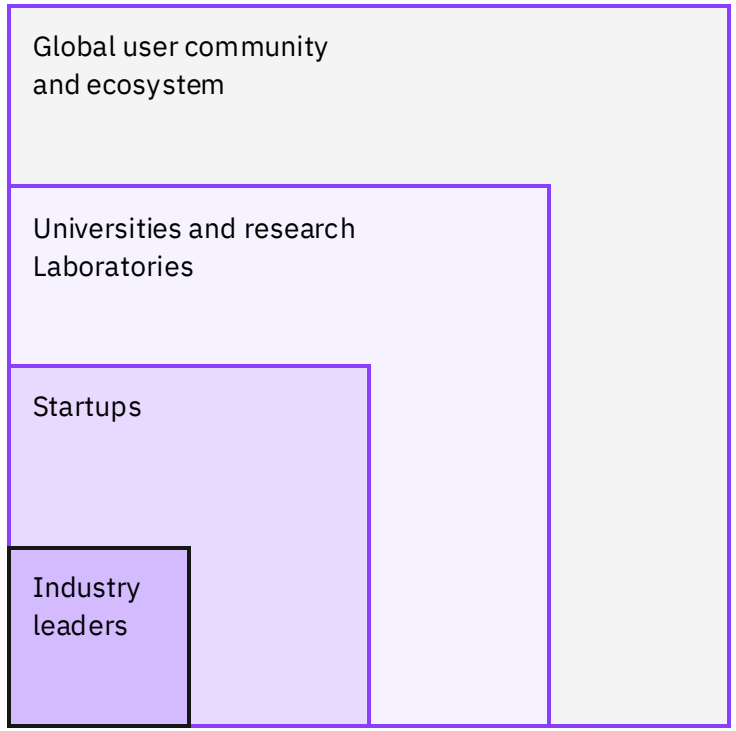
IBM Quantum Network

Global community driving innovation

The **IBM Quantum Network** is a global collective of 250+ Fortune 500 companies, universities, laboratories and startups shaping the future of quantum computing with access to exclusive meetings and select channels.



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Accelequant
Adam Mickiewicz University
Agnostiq Inc
Alabama A&M University
Alabama State University
Albany State University
Algorithmiq Oy
Aliro Quantum
American Express
Anaqor
AngelQ
Ansys Inc
Applied Quantum Computing
Aqarios
Argonne National Lab
Arizona State University
Assured Information Security
Banco Bilbao Vizcaya Argentaria
Banco Bradesco
Basque Center for Climate Change
Basque Center for Neuroscience (Achucarro)
Basque Center on Cognition, Brain and Language
Beit
Biofisika Institute
BlueQubit
Boeing
Bosch
BosonQ Psi
Boston University
Bowie State University
Brookhaven National Lab
Bundeswehr University Munich
CERN
CIC energiGUNE
CMC Microsystems
Cambridge Quantum Computing
Capgemini SE
Carnegie Mellon Software Engineering Institute
Case Western Reserve University
Center for Cooperative Research for Biosciences
Center for Cooperative Research in Biomaterials
Center for Theoretical Physics Polish Academy of Sciences
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Hyundai Motor Company
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Istituto Italiano di Tecnologia
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Jij Inc.
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Johns Hopkins University
KEIO University
KPMG
Kent State University
Kipu Quantum
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Korea Advanced Institute of Science and Technology
Korea Quantum Computing Corporation
Korea University
Kyunghee University
LG ELECTRONICS, INC
LTIMindtree
Lantik SA
Lantik members
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Lawrence Livermore National Laboratory
Lehigh University
Lockheed Martin
Los Alamos National Laboratory
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Mizuho Bank
Moderna
Mondragon Unibertsitatea
Morehouse College
Morgan State University
Multiverse Computing
National Energy Technology Laboratory
National Institute for Nuclear Physics
National Quantum Computing Centre
National Taiwan University
National University of Singapore
Naval Air Warfare Center Aircraft Division
Naval Air Warfare Center Weapons Div.
Naval Information Warfare Center Atlantic Command
Naval Information Warfare Center Pacific Command
Naval Surface Warfare Center
Netherlands Organization for Applied Scientific Research
Netherlands eScience Center
New Mexico State University
New York University
Norfolk State University
North Carolina AT State University
North Carolina Central University
North Carolina State University
Northeastern University
Northwestern University
OESIA
OVH Groupe SA
Oak Ridge National Lab
Pacific Northwest National Lab
Perimeter Institute for Theoretical Physics
Phasecraft
Plateforme d'Innovation Numerique et Quantique
Polymat
Poznan Supercomputing and Networking Center
Prairie View AM University
PricewaterhouseCoopers
Purdue University
Q-Ctrl
QAI Ventures
QC Design
QC Ware
QCENTROID
QEDMA Quantum Computing
QbitSoft
Qognitive
Qruise GmbH
Quanscient
Quantagonia
Quantum Algorithms Institute
Quantum Application Lab
Quantum MADS
Quantum South
Quantum Technology Foundation of Thailand
QuantumBasel
QuantumNET
QubitSolve Inc
Qunasys
Qunova Computing
RIKEN National Research and Development Agency
Rensselaer Polytechnic Institute
Riverlane
SK Inc. C&C
STFC Hartree Centre (UKRI)
Sandia National Labs
School of Engineering, Zürcher Hochschule für Angewandte Wissenschaften
Seoul National University
SeoulTech
SoftBank
Sony
South Carolina State University
Southern University and A&M College
Spelman College
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United States Air Force Research Lab
United States Naval Postgraduate Military University
United States Naval Research Laboratory
United States Naval Undersea Warfare Center
Universite de Sherbrooke
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University of the District of Columbia Community College
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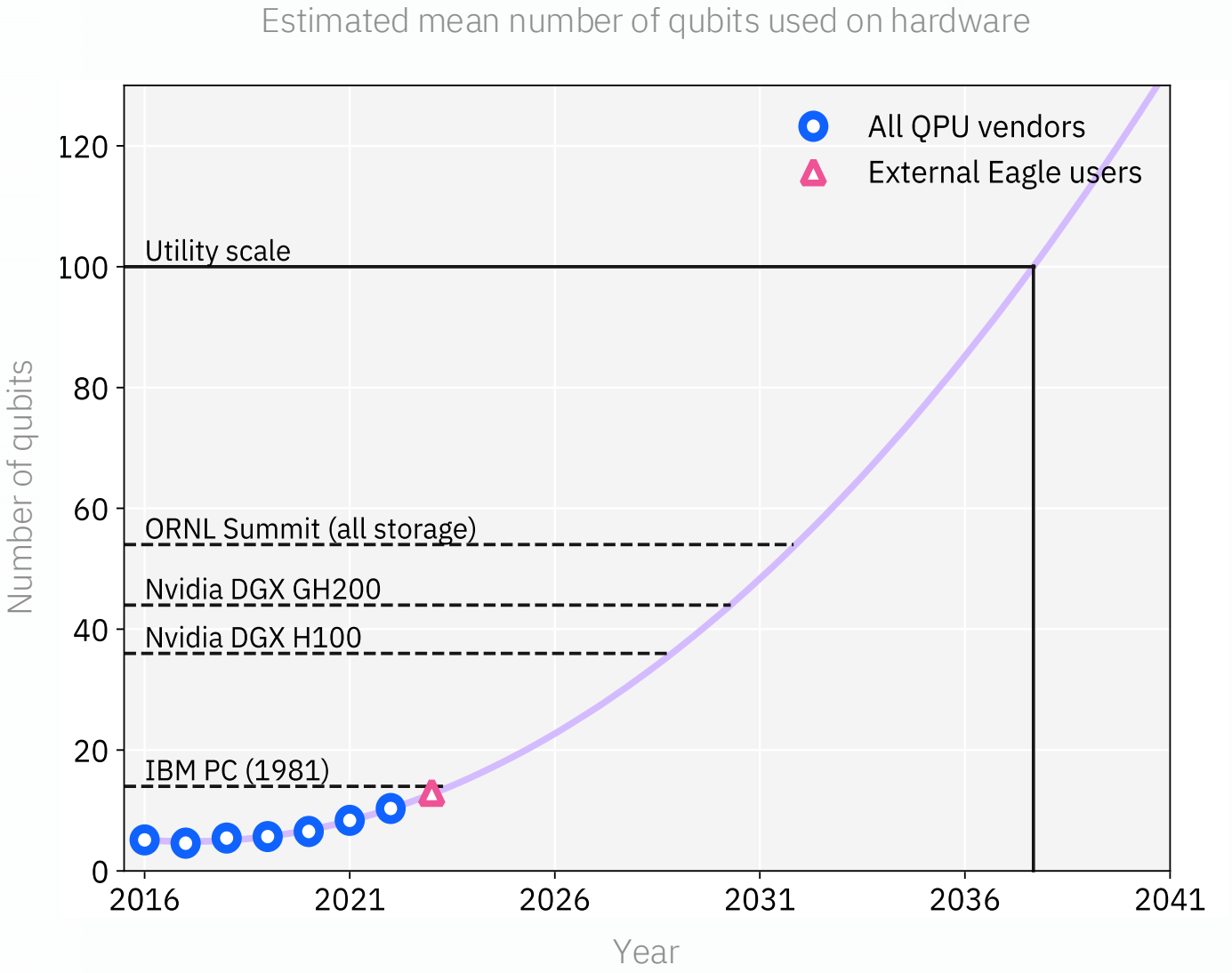
Vicomtech
Virginia Tech
Virginia Union University
Vodafone Group
Volkswagen
WACQT
Wells Fargo
Woodside Energy Ltd
Xavier University of Louisiana
Yokogawa Electric Corporation
Yonsei University
Zapata Computing Inc
qBraid Co

When may these efforts bring useful results ?

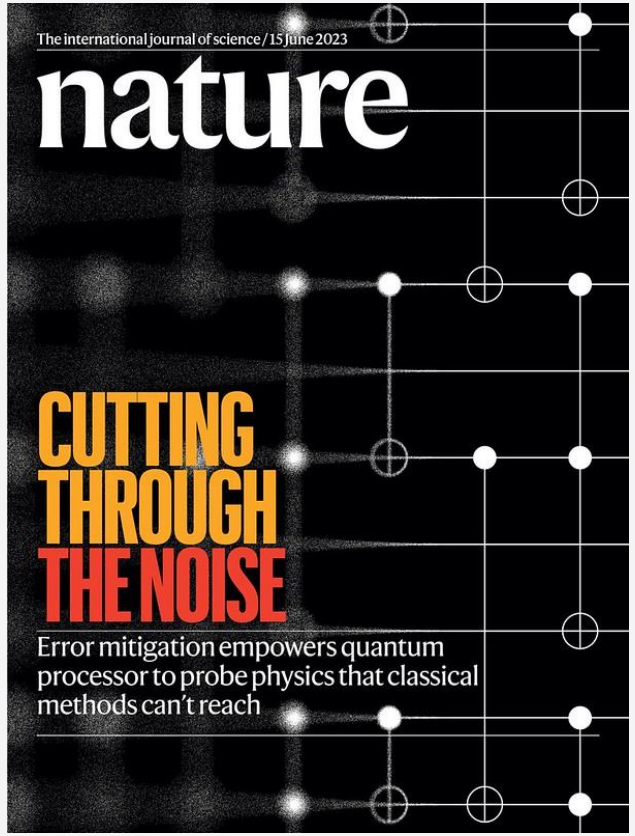
Quantum state of play



Data for all vendors taken from: arXiv:2307.16130

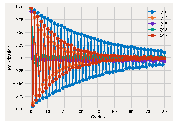
→ June 2023

A noisy quantum computer is able to produce accurate expectation values on 127 qubits; outside of brute force classical computation



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

If you build it, they will come…

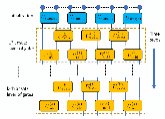


Characterizing quantum processors using discrete time crystals
arXiv:2301.07625
80 qubits / 7900 CX gates

simulation

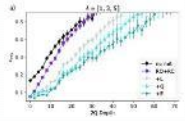
Evidence for the utility of quantum computing before fault tolerance
Nature, 618, 500 (2023)
127 qubits / 2880 CX gates

simulation



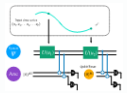
Simulating large-size quantum spin chains on cloud-based superconducting quantum computers
Phys. Rev. Research 5, 013183 (2023)
102 qubits / 3186 CX gates

simulation



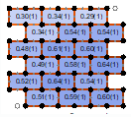
Best practices for quantum error mitigation with digital zero-noise extrapolation
arXiv:2307.05203
104 qubits / 3605 ECR gates

tools



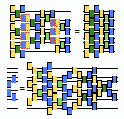
Quantum reservoir computing with repeated Measurements on superconducting devices
arXiv:2310.06706
120 qubits / 49470 ECR gates + meas.

QML



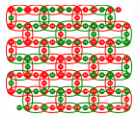
Realizing the Nishimori transition across the error threshold for constant-depth quantum circuits
arXiv:2309.02863
125 qubits / 429 gates + meas.

simulation



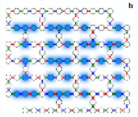
Scalable Circuits for Preparing Ground States on Digital Quantum Computers: The Schwinger Model Vacuum on 100 Qubits
PRX Quantum 5, 020315 (2024)
100 qubits / 788 CX gates

simulation



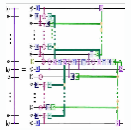
Scaling Whole-Chip QAOA for Higher-Order Ising Spin Glass Models on Heavy-Hex Graphs
arXiv:2312.00997
127 qubits / 420 CX gates

optimization



Uncovering Local Integrability in Quantum Many-Body Dynamics
arXiv:2307.07552
124 qubits / 2641 CX gates

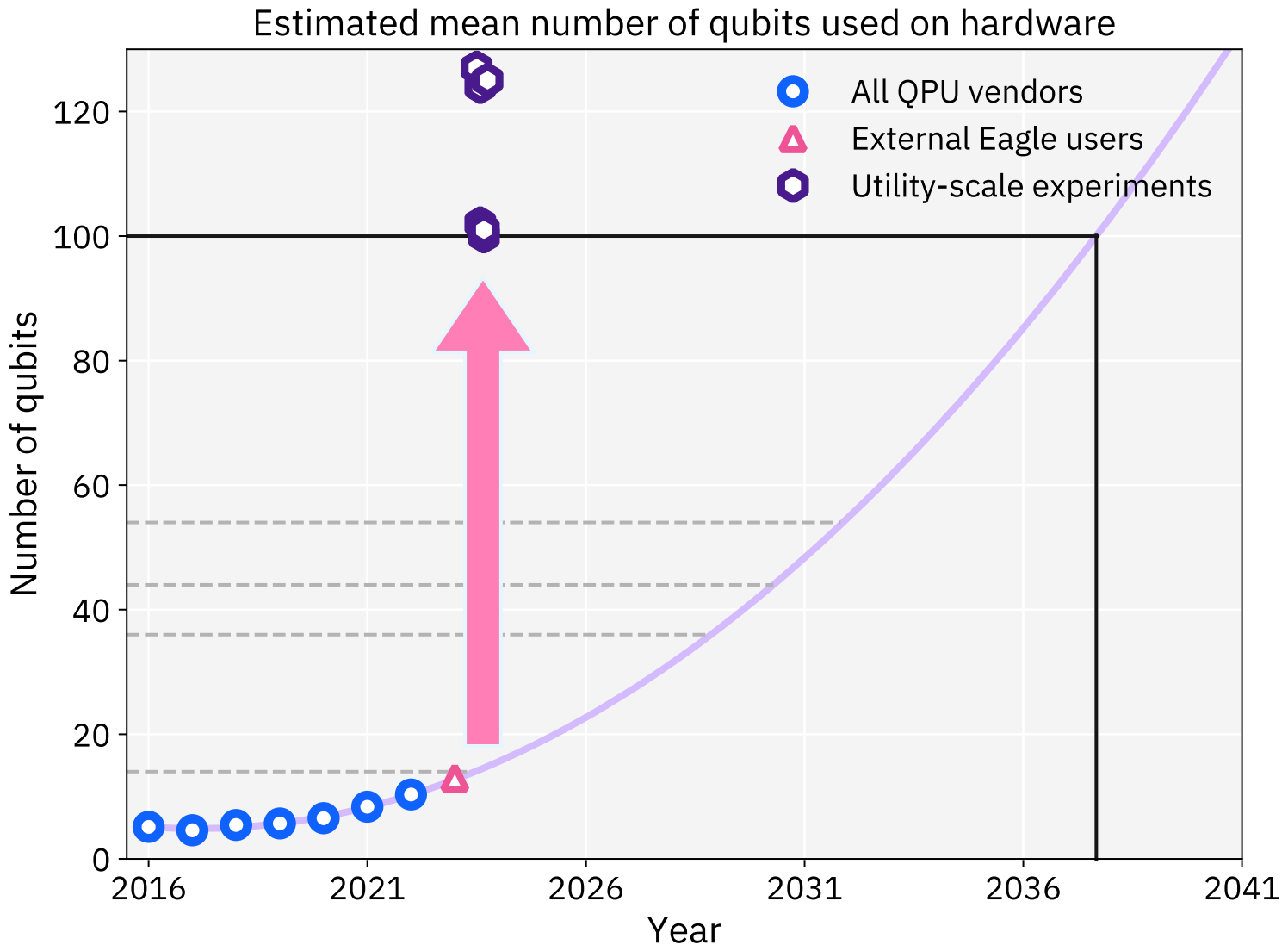
simulation

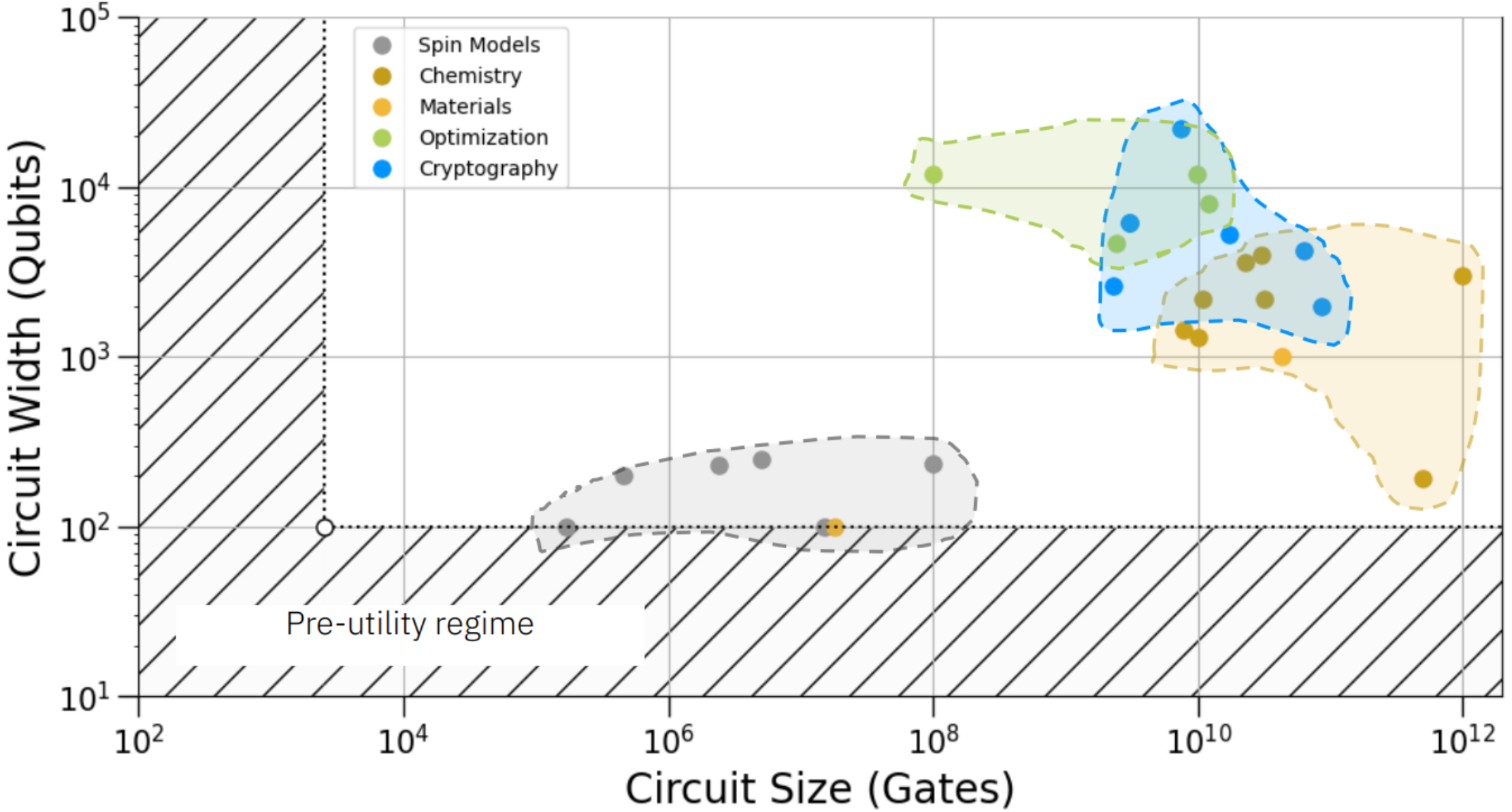


Efficient Long-Range Entanglement using Dynamic Circuits
arXiv:2308.13065
101 qubits / 504 ECR gates + meas

tools

Quantum state of play




Spin Models
Chemistry
Materials
Optimization
Cryptography
Pre-utility regime
Circuit Width (Qubits)
Circuit Size (Gates)
10^1
10^2
10^3
10^4
10^5
10^2
10^4
10^6
10^8
10^{10}
10^{12}

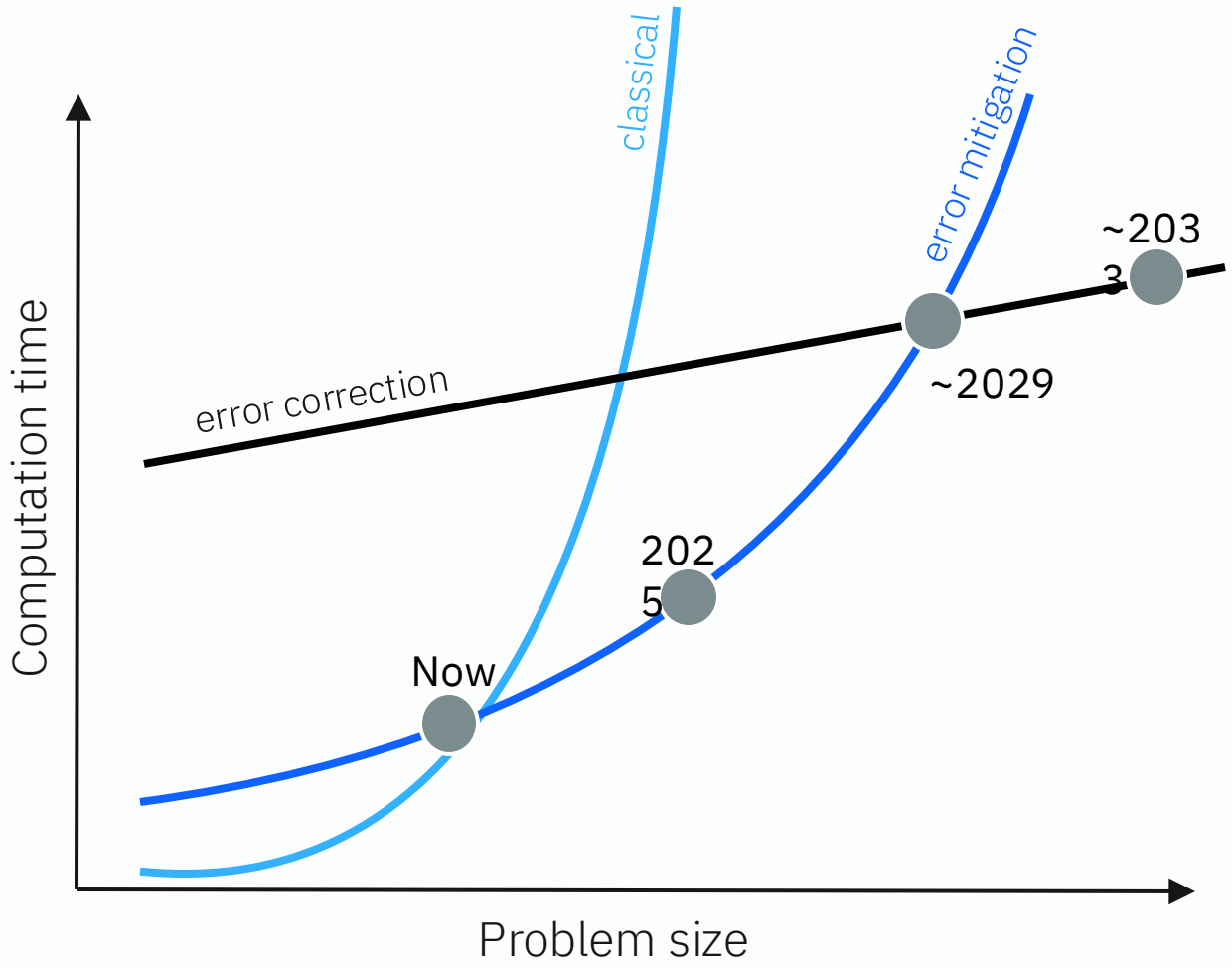
Development Roadmap

IBM **Quantum**

	2016–2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2033+
	Ran quantum circuits on the IBM Quantum Platform	Released multi-dimensional roadmap publicly with initial aim focused 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	Improve quantum circuit quality and speed to allow 5K gates with parametric circuits	Enhance quantum execution speed and parallelization with partitioning and quantum modularity	Improve quantum circuit quality to allow 7.5K gates	Improve quantum circuit quality to allow 10K gates	Improve quantum circuit quality to allow 15K gates	Improve quantum circuit quality to allow 100M gates	Beyond 2033, quantum-centric supercomputers will include 1000's of logical qubits unlocking the full power of quantum computing
Data scientists						Platform						
						Code assistant	Functions	Mapping collections	Specific libraries			General purpose QC libraries
Researchers					Middleware							
					Quantum Serverless	Transpiler service	Resource management	Circuit knitting x p	Intelligent orchestration			Circuit libraries
Quantum physicists			Qiskit Runtime									
	IBM Quantum Experience		QASM 3	Dynamic circuits	Execution modes	Heron (5K)	Flamingo (5K)	Flamingo (7.5K)	Flamingo (10K)	Flamingo (15K)	Starling (100M)	Blue Jay (1B)
						Error mitigation 5k gates 133 qubits Classical modular 133x3 = 399 qubits	Error mitigation 5k gates 156 qubits Quantum modular 156x7 = 1092 qubits	Error mitigation 7.5k gates 156 qubits Quantum modular 156x7 = 1092 qubits	Error mitigation 10k gates 156 qubits Quantum modular 156x7 = 1092 qubits	Error mitigation 15k gates 156 qubits Quantum modular 156x7 = 1092 qubits	Error correction 100M gates 200 qubits Error corrected modularity	Error correction 1B gates 2000 qubits Error corrected modularity
	Early Canary 5 qubits Albatross 16 qubits Penguin 20 qubits Prototype 53 qubits	Falcon Benchmarking 27 qubits		Eagle Benchmarking 127 qubits								

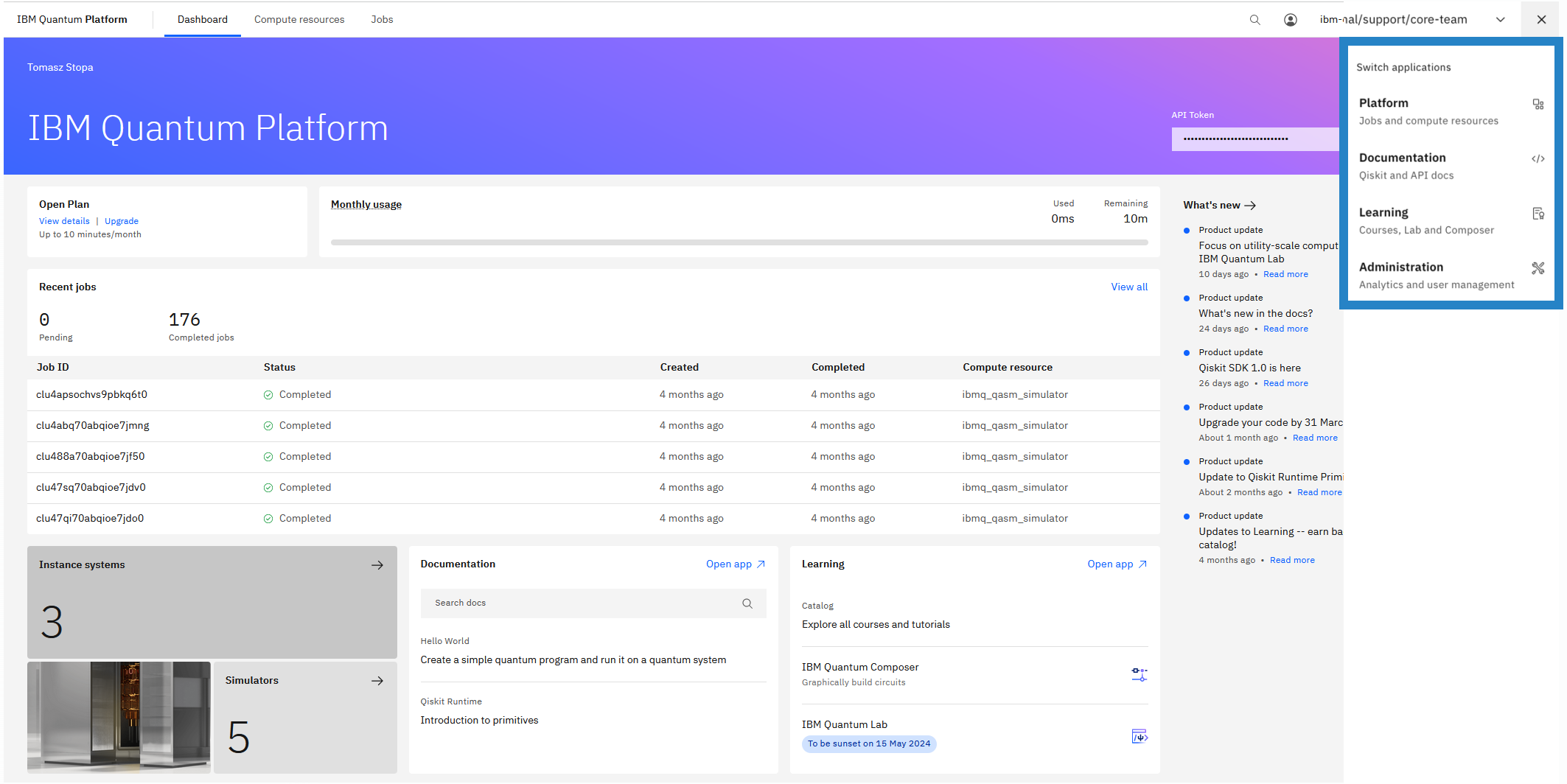
Innovation Roadmap

Software innovation	IBM Quantum Experience	Qiskit Circuit and operator API with compilation to multiple targets	Application modules Modules for domain specific application and algorithm workflows	Qiskit Runtime Performance and abstraction through primitives	Quantum Serverless Demonstrate concepts of quantum-centric supercomputing	AI-enhanced quantum Prototype demonstrations of AI-enhanced circuit transpilation	Resource management System partitioning to enable parallel execution	Scalable circuit knitting Circuit partitioning with classical reconstruction at HPC scale	Error correction decoder Demonstration of a quantum system with real-time error correction decoder			
Hardware innovation	Early Canary 5 qubits Penguin 20 qubits Albatross 16 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 modular connectors	Kookaburra Demonstrate scaling with nonlocal c-coupler Demonstrate path to improved quality with logical memory		Cockatoo Demonstrate path to improved quality with logical communication	Starling Demonstrate path to improved quality with logical gates	
						Heron Architecture based on tunable-couplers	Crossbill Demonstrate m-couplers					


classical
error mitigation
~203
3
error correction
~2029
202
5
Now
Computation time
Problem size

How YOU can run programs on real quantum computer?

quantum.ibm.com



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IBM Quantum Lab will be sunset on 15 May 2024. Learn more →

IBM Quantum Learning

Learn the basics of quantum computing, and how to use IBM Quantum services and systems to solve real-world problems.

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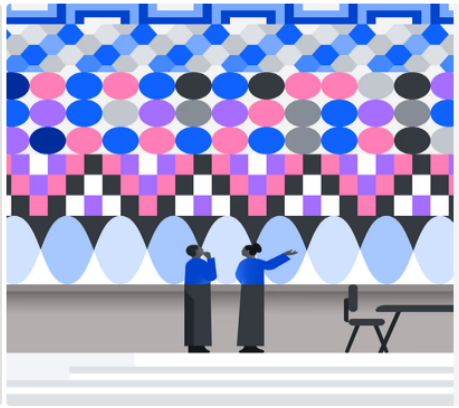


Fundamentals of quantum algorithms

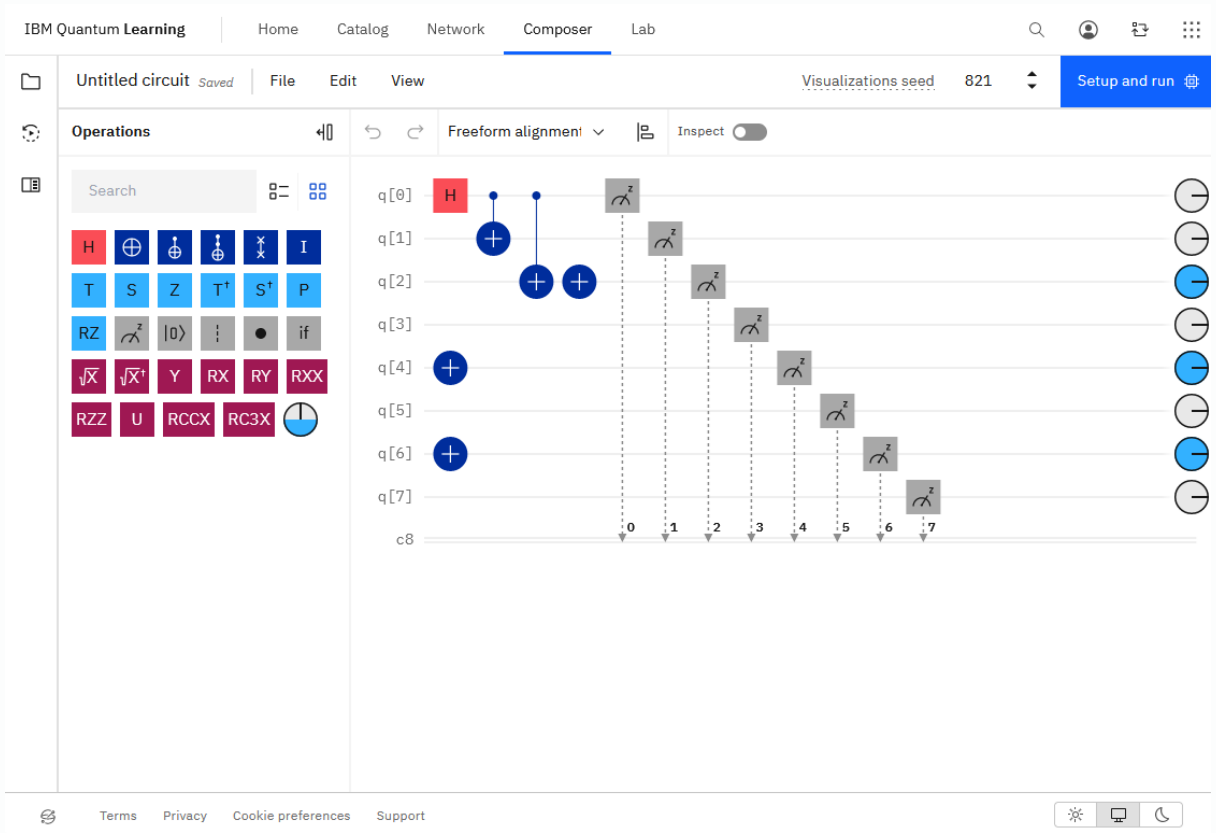
Video

Use quantum computers to solve problems more efficiently, including problems with real-world relevance such as searching and factoring.

Lessons 4

Your progress 0%

Start course →



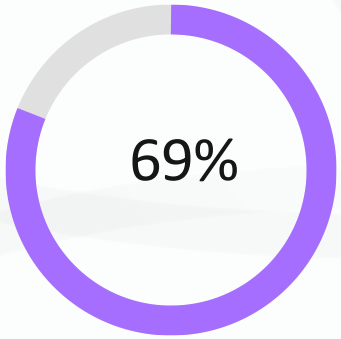
The de facto standard for the creation, optimization, and execution of quantum circuits and operators.

Qiskit 1.2

The lingua franca of quantum computing; write once and execute quantum circuits on 8+ different hardware manufacturers

- Alpine Quantum
- Amazon Braket
- Azure Quantum
- IBM Quantum
- IonQ
- IQM
- Quantinuum
- Rigetti

SDK preferred by 69% of quantum programmers
(2023 Unitary Fund survey)



What does tech decision makers say?

Those who use **IBM Quantum** systems expect to see ROI from quantum computing **within 3-6 years**

AWS users are a bit more optimistic estimating that ROI will arrive in **3-4 years**

Google users land more in the **5-6 year** time range

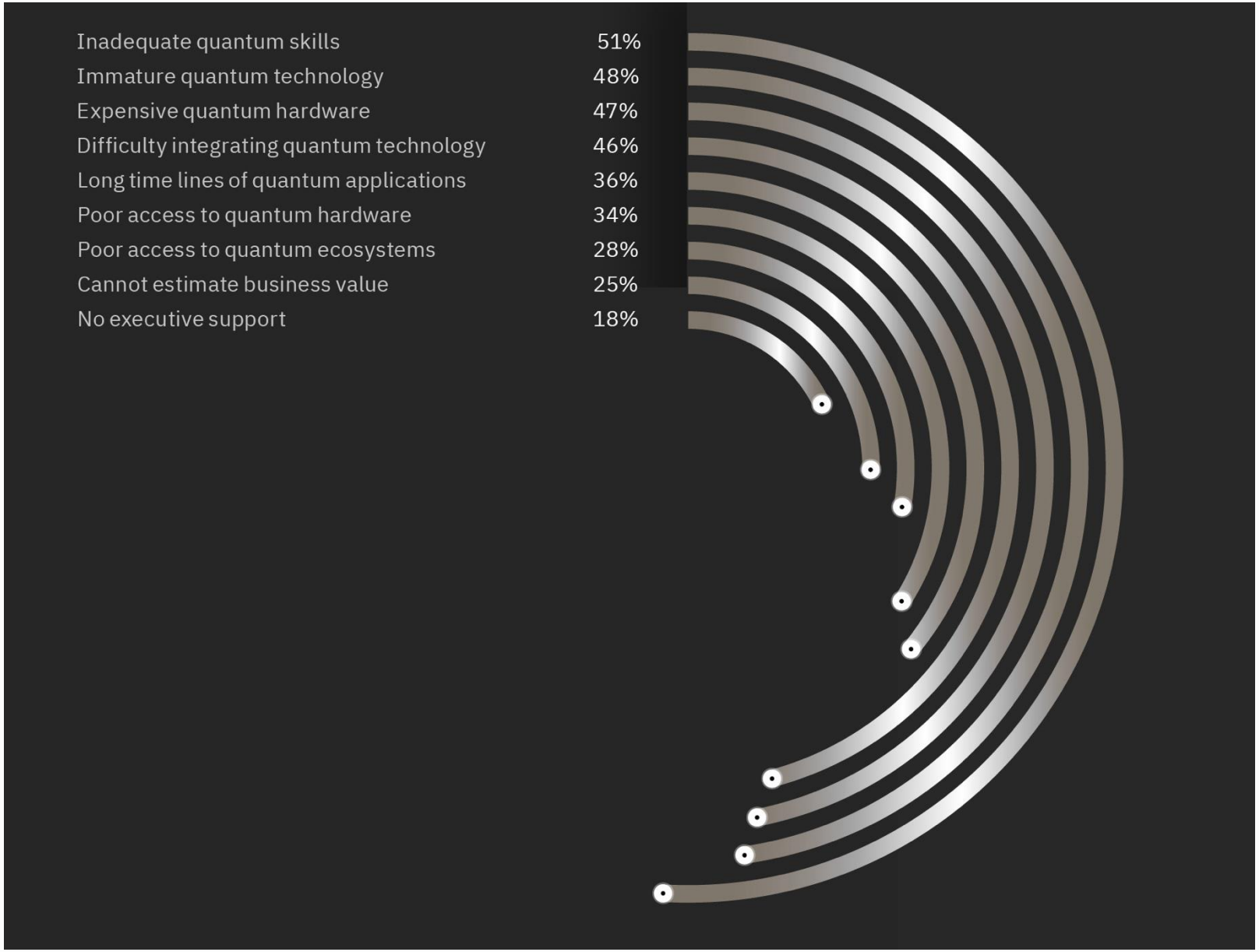
More than 1/3 of **non-users of quantum systems** estimate ROI for more than **7 years away**

Source: 2024 third annual IBM Quantum Computing Brand Health Panel survey

23%

of the technology workforce is expected to expand skills to gain quantum expertise over the next 3 years

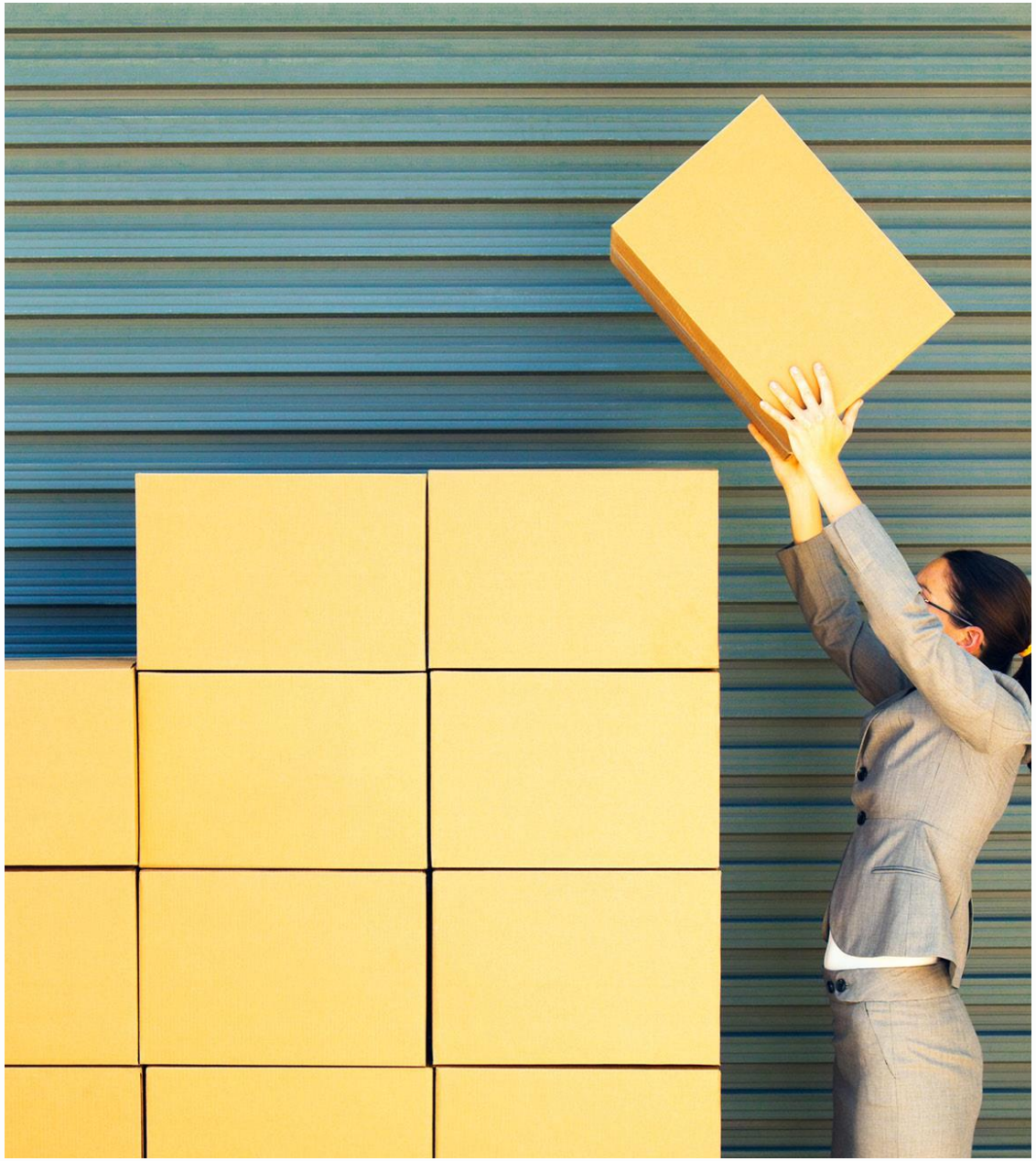
Inadequate skills is the top barrier to adopting quantum computing



...for every three current quantum technology job openings today, the United States has only one qualified candidate—and by 2025, McKinsey analysts predict, more than half of the country's quantum jobs will go unfilled.

13 years

is the time period by which organizations expect to fully integrate quantum computing into their business.



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HSBC and Quantum

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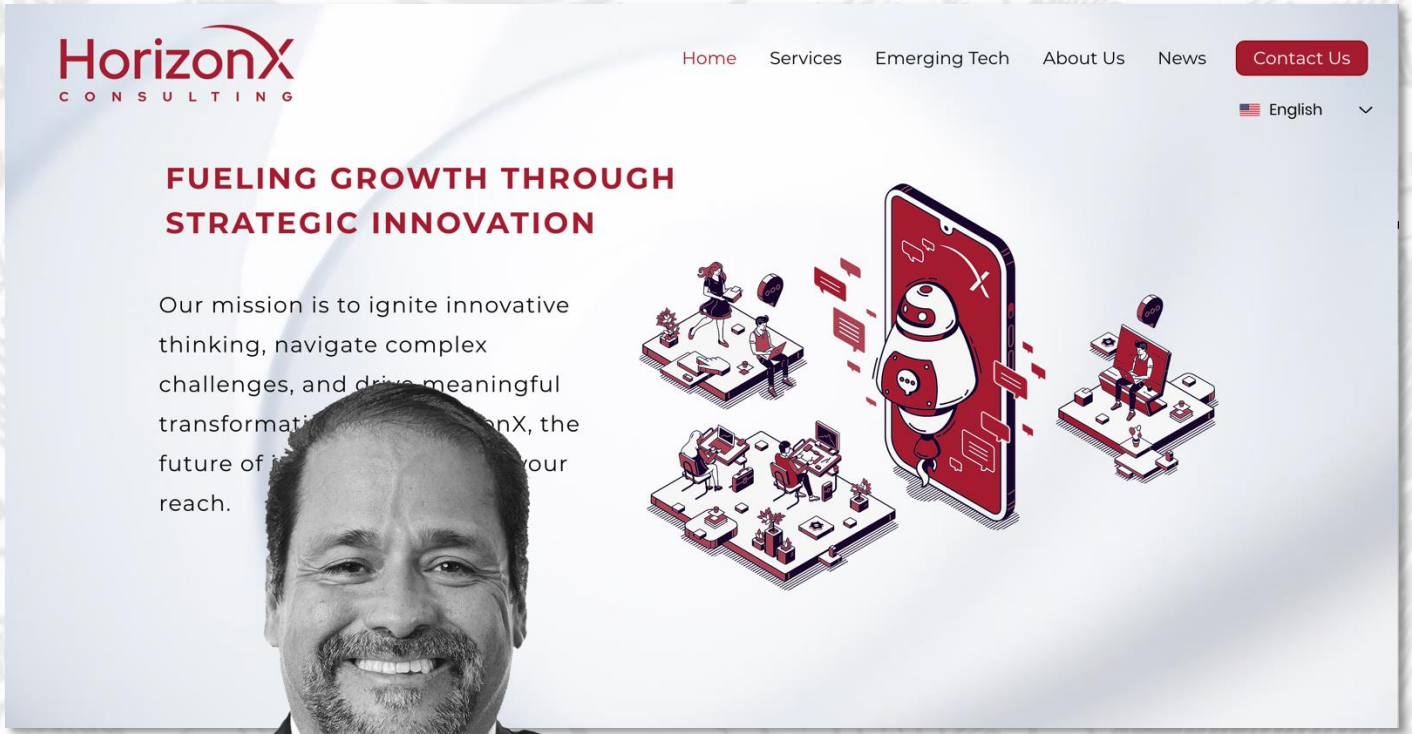
HSBC Working with IBM to Accelerate Quantum Computing Readiness

Bank envisions application of quantum capabilities for priorities such as pricing and portfolio optimisation, sustainability, risk and fraud

Expands internal talent with quantum specialists

Mar 29, 2022



HorizonX

Steve Suarez
Founder and CEO

IBM
Silver Partner

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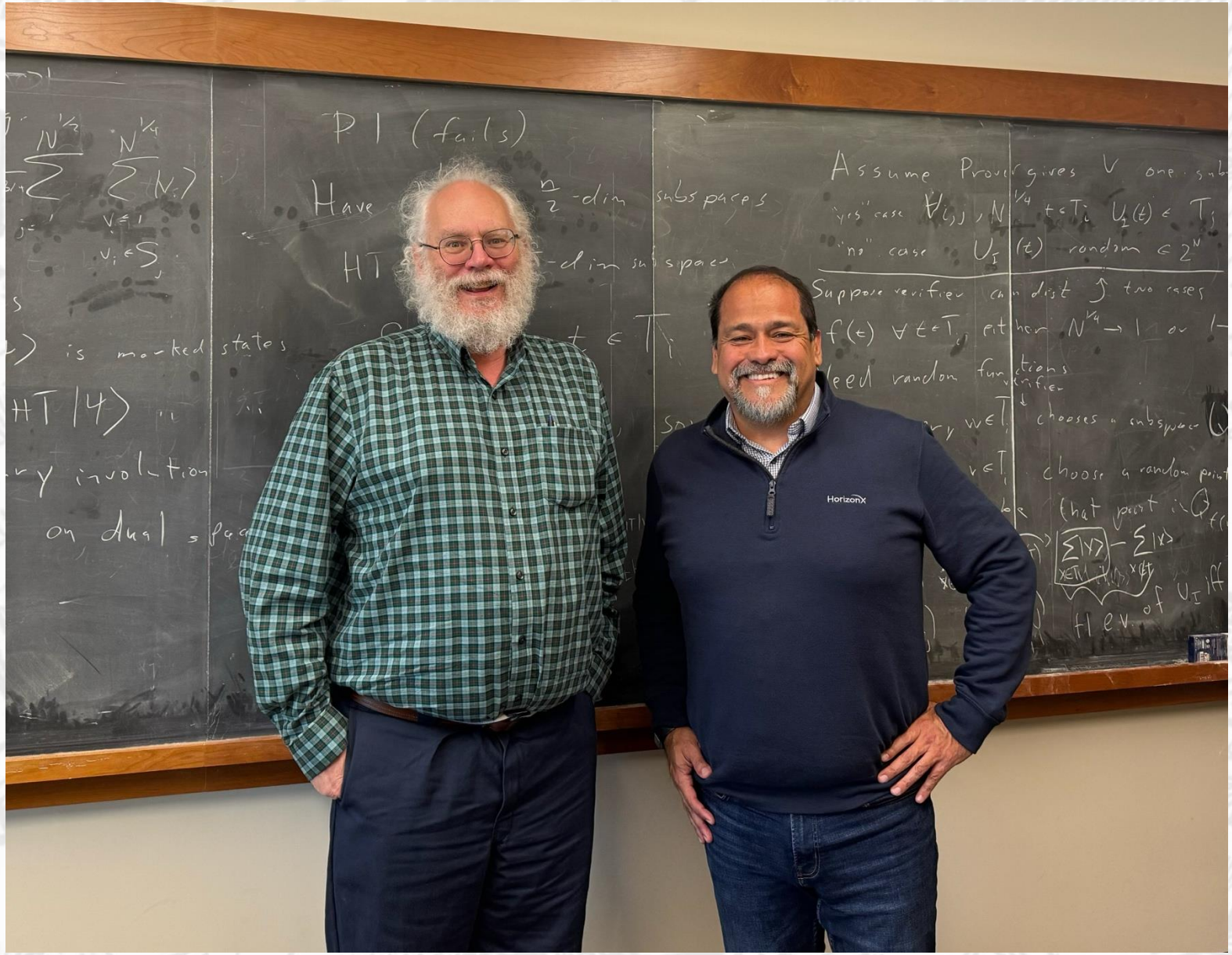
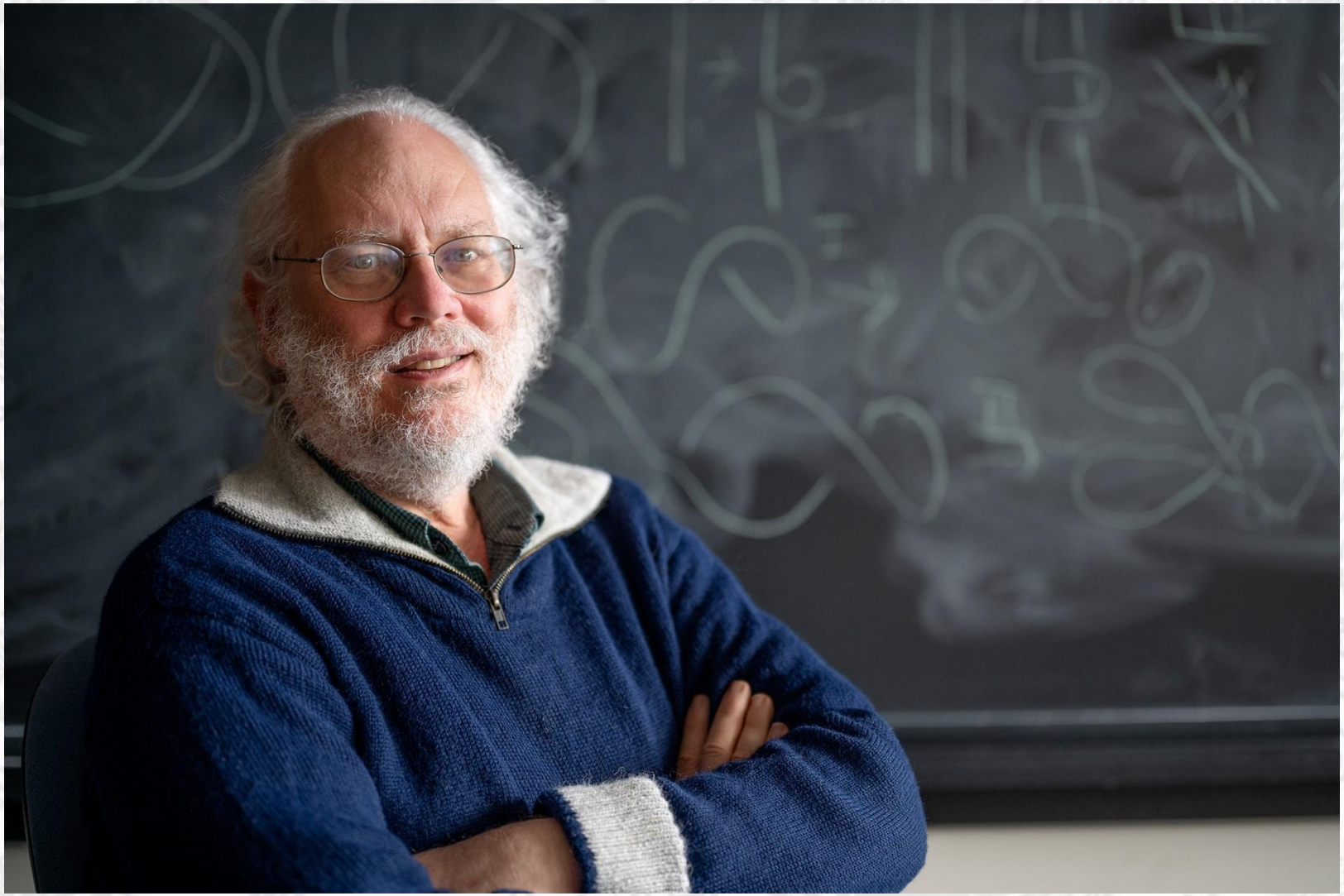
Professor of Physics, Professor of Electrical Engineering and Computer Science, MIT

Steve Suarez
Founder & CEO HorizonX Consulting, Ex-HSBC, External Advisor @ Bain & Company

October 15 , 2024

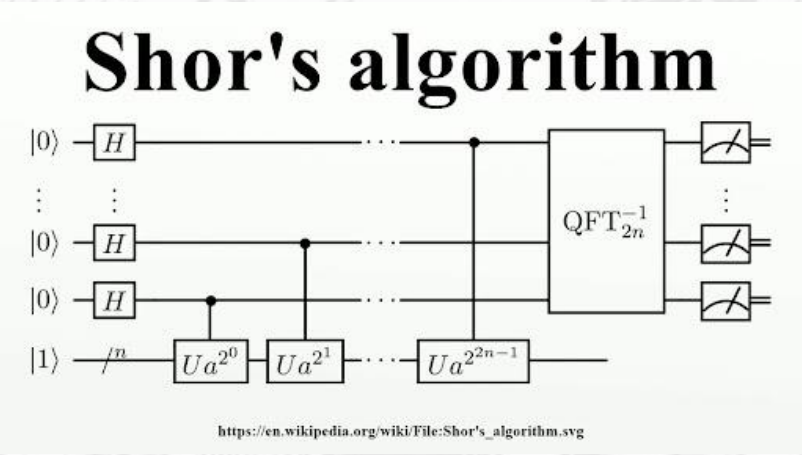
investment in QuEra


P1 (fails)
Have
HT
is marked states
HT|4⟩
on dual
Assume Prover gives V one sub
"yes" case
"no" case
Suppose verifier
two cases
choose a random point
that point is
of U_I iff



Peter Shor

(born August 14, 1959) is an American theoretical computer scientist known for his work on quantum computation, in particular for devising Shor's algorithm, a quantum algorithm for factoring exponentially faster than the best currently-known algorithm running on a classical computer. He has been a professor of applied mathematics at the Massachusetts Institute of Technology (MIT) since 2003.



Phone Exercise

Q&A

IBM Quantum

IBM Quantum Platform
https://quantum.ibm.com

Access to your account via the platform, the documentation about Qiskit and Qiskit Runtime and learning materials

Github organization
https://github.com/Qiskit

Find all repositories related to qiskit, such as the documentation, runtime, qiskit itself, etc.

Slack workspace
https://qisk.it/join-slack

Open slack workspace with all the Qiskit community, lots of channels dedicated to specific subjects

Youtube channel
https://www.youtube.com/Qiskit

Videos related to QI/QC and Qiskit, access to seminars, paper reviews, tips about Qiskit, etc.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BEYOND THE BUBBLE
THANK YOU