

The path to quantum advantage at IBM Quantum

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Quantum Advantage: A quantum computer can outperform classical computing resources in one or more limited real-world applications.



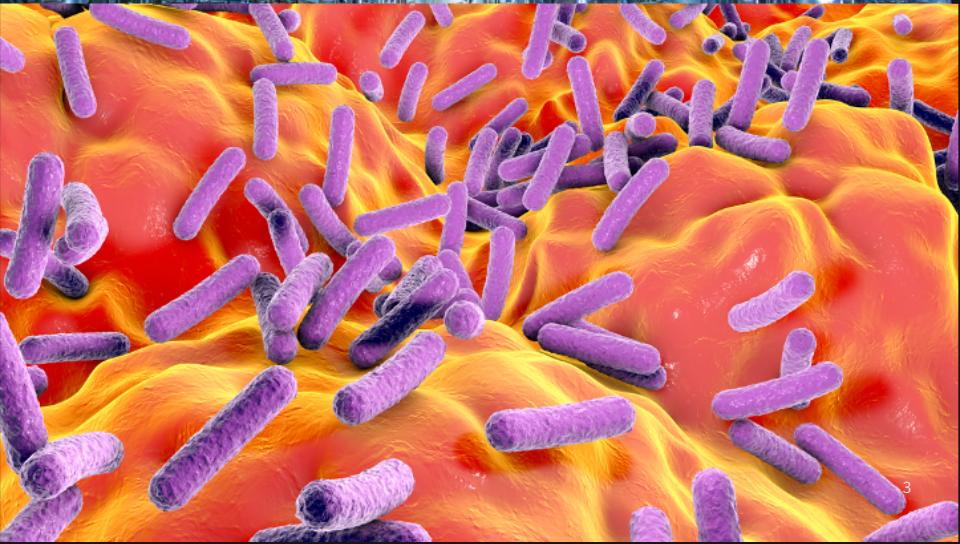
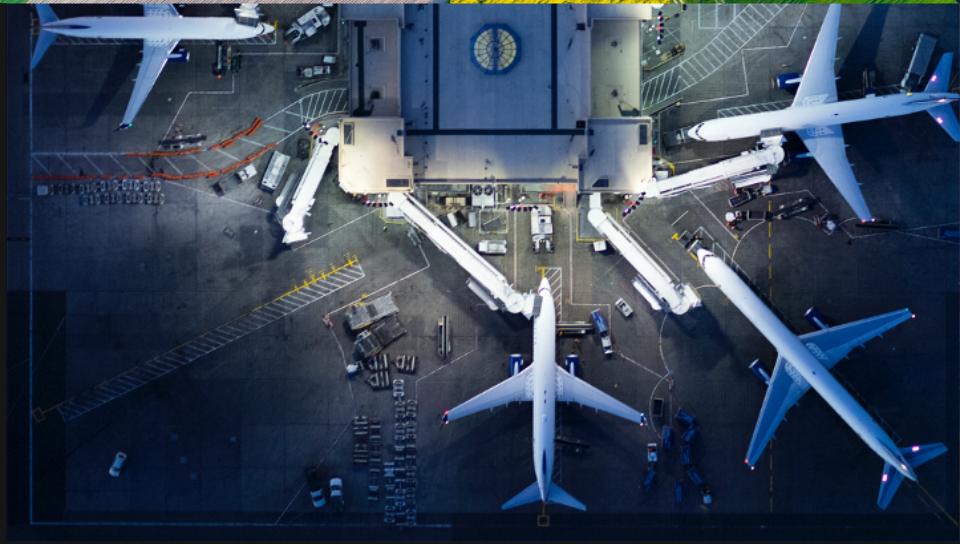
Ideal

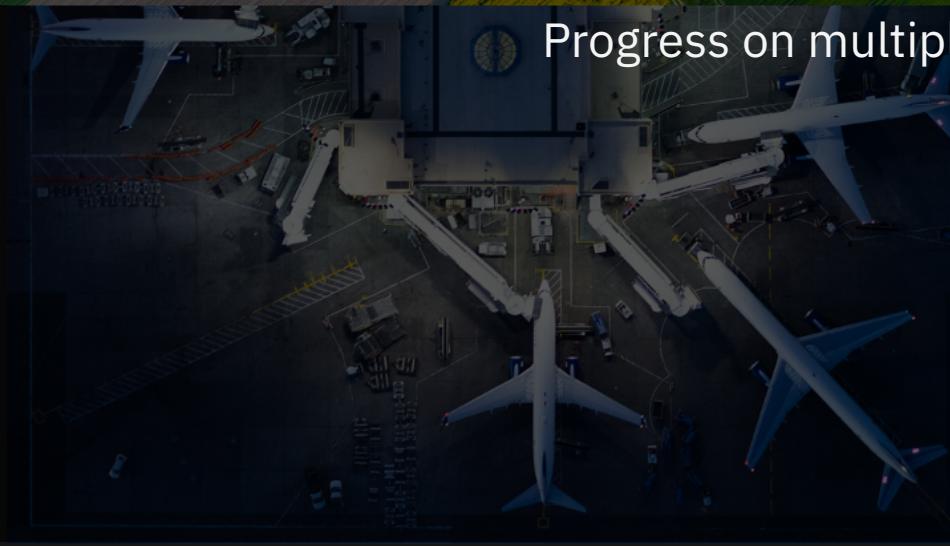
Rigorous mathematical proof.



Practical

If it accelerates workflows enough for people to pay you for it.





Qubit count and quality alone are not enough.
Progress on multiple fronts is required.

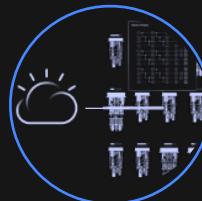
Key driving metrics toward quantum advantage



Quality

What is the quality of circuits and how well are circuits implemented in hardware?

2019	Today	2021
32 QV	128 QV	256 QV



Speed

How fast can circuits be executed on quantum hardware?

2019	TODAY
45 days to run chemistry computation	0.8 days (9 hours) to run chemistry computation



Scalability

How to increase size and performance of systems over time?

2019	Today	2021
27 qubits	65 qubits	127 qubits

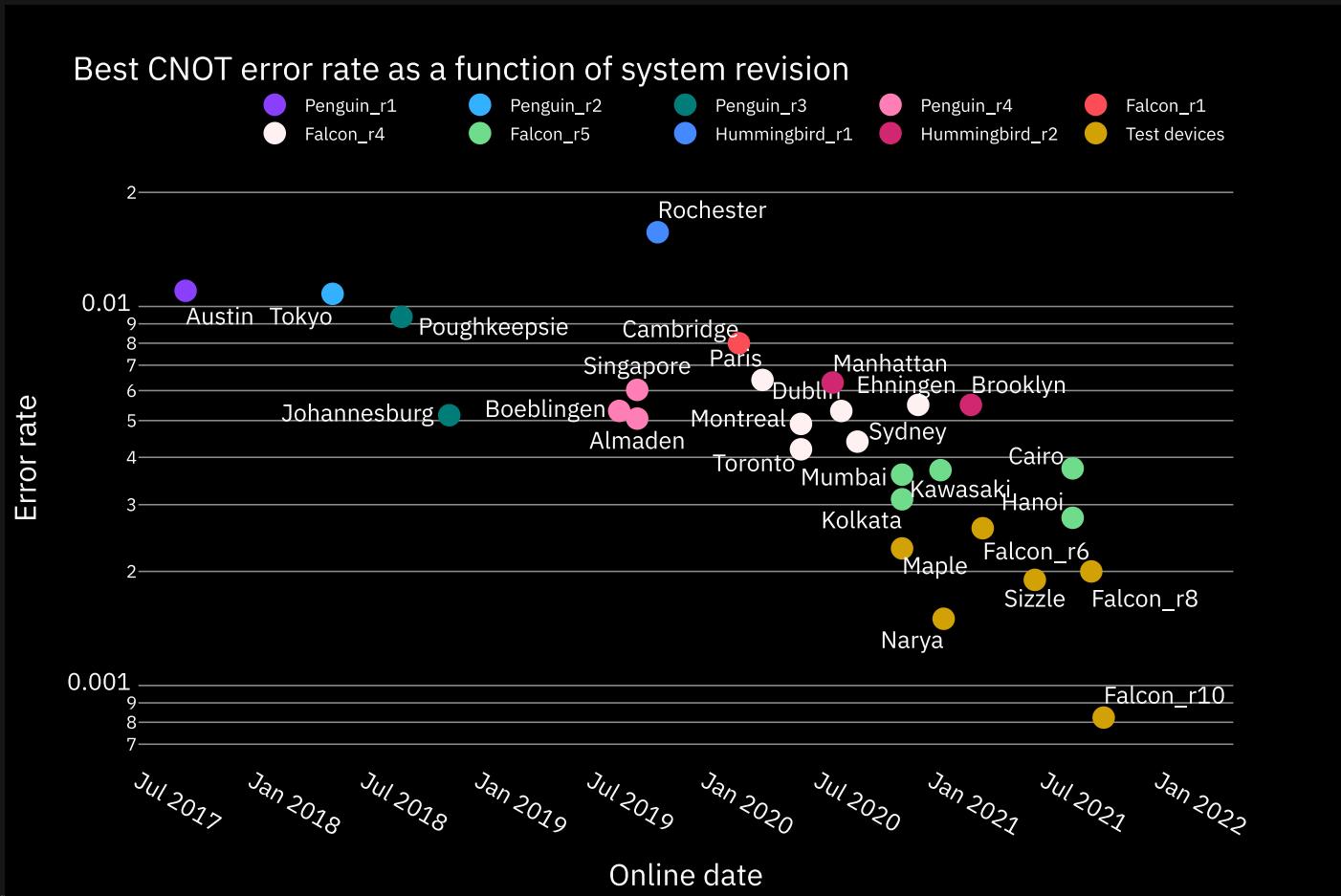


Adoption

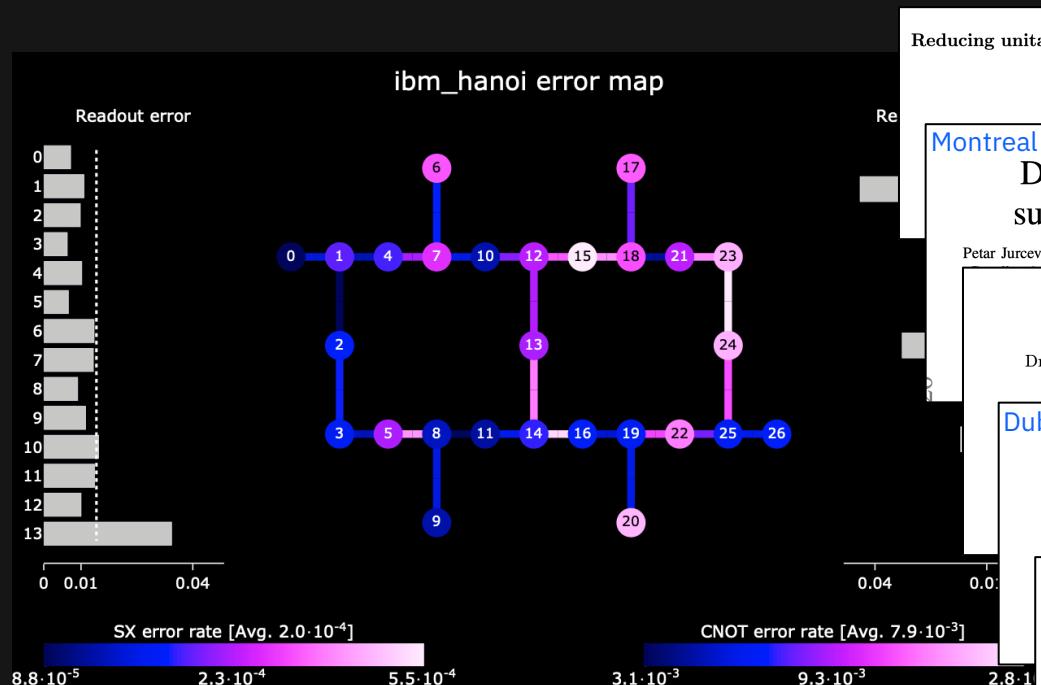
How broad is the demonstrated use of the systems?

2019	Today	2021
0.6B circuits/day	2B circuits/day	4B circuits/day

Quality



Quality



Reducing unitary and spectator errors in cross-resonance with optimized rotary echoes

Neereja Sundaresan,* Isaac Lauer,* Emily Pritchett,* Easwar Magesan,* Petar Jurcevic, and Jay M. Gambetta
IBM Quantum, T. J. Watson Research Center, Yorktown Heights, NY 10598

Montreal

Demonstration of quantum volume 64 on a superconducting quantum computing system

Petar Jurcevic*, Ali Javadi-Abhari*, Lev S. Bishop*, Isaac Lauer*, Daniela F. Bogorin*, Markus Brink*, Laurence M. Risch†, and Michael J. Hickey‡

Berlin

Quantum advantage for computations with limited space

Dmitri Maslov,¹ Jin-Sung Kim,² Sergey Bravyi,¹ Theodore J. Yoder,¹ and Sarah Sheldon²
¹*IBM Quantum, IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA*

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Doubling the size of quantum simulators by entanglement forging

Andrew Eddins,¹ Mario Motta,¹ Tanvi P. Gujarati,¹ Sergey Bravyi,²
Antonio Mezzacapo,² Charles Hadfield,² and Sarah Sheldon¹

¹IBM Quantum, Almaden Research Center, San Jose, California 95120, USA
²IBM Quantum, T. J. Watson Research Center, Yorktown Heights, NY 10598, USA

Kolkata

Covariant quantum kernels for data with group structure

Jennifer R. Glick,¹ Tanvi P. Gujarati,² Antonio D. Corcoles,¹ Youngseok Kim,¹ Abhinav Kandala,¹ Jay M. Gambetta,¹ and Kristan Temme^{1,*}

¹IBM Quantum, IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA

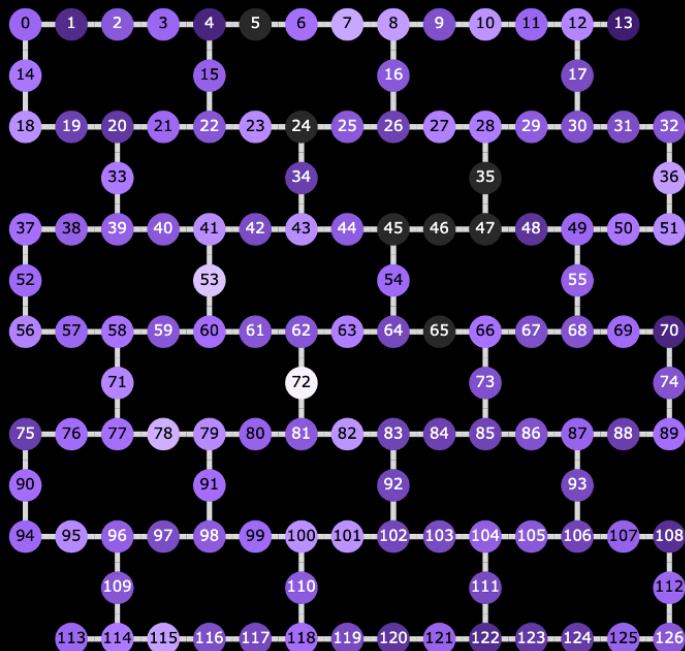
IBM Quantum, Almaden Research Center, San Jose, California 95120, USA

(Dated: May 7, 2021)

(Dated: May 1, 2021)

Scalability: Hardware

Eagle (127 qubits)

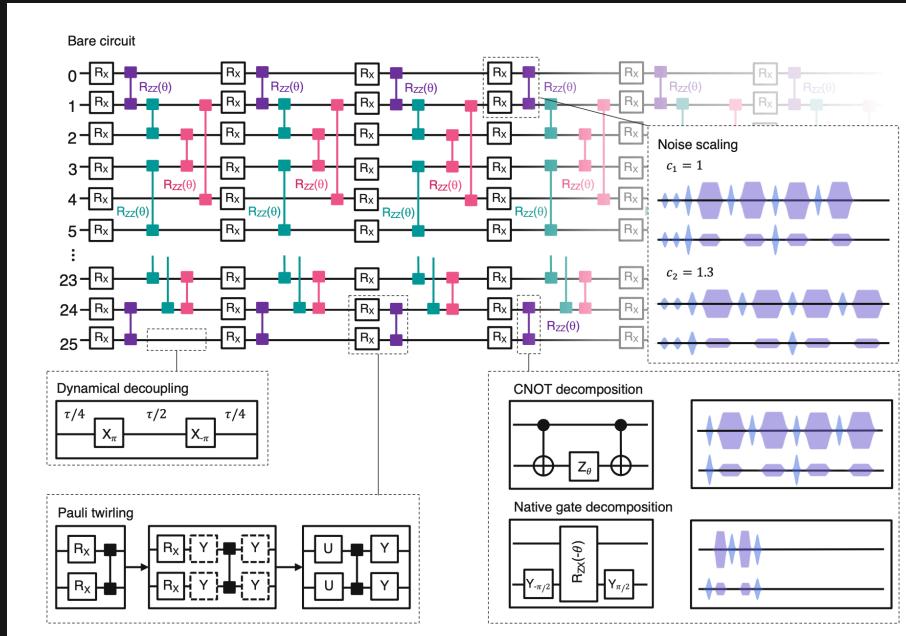


Cutting edge system for exploring beyond classical compute.

Largest cloud-accessible quantum system to date.

Targeted for researchers looking to push the boundary of what is possible in quantum computing.

Scalability: Mitigation methods



Zero-noise extrapolation out to 26 qubits and over 1000 cnot gates with Pauli twirling and dynamical decoupling.

Accuracy beyond what is possible using tensor-network simulation methods.

Can begin to think about mitigation of gate errors out to numbers of qubits where advantage is.

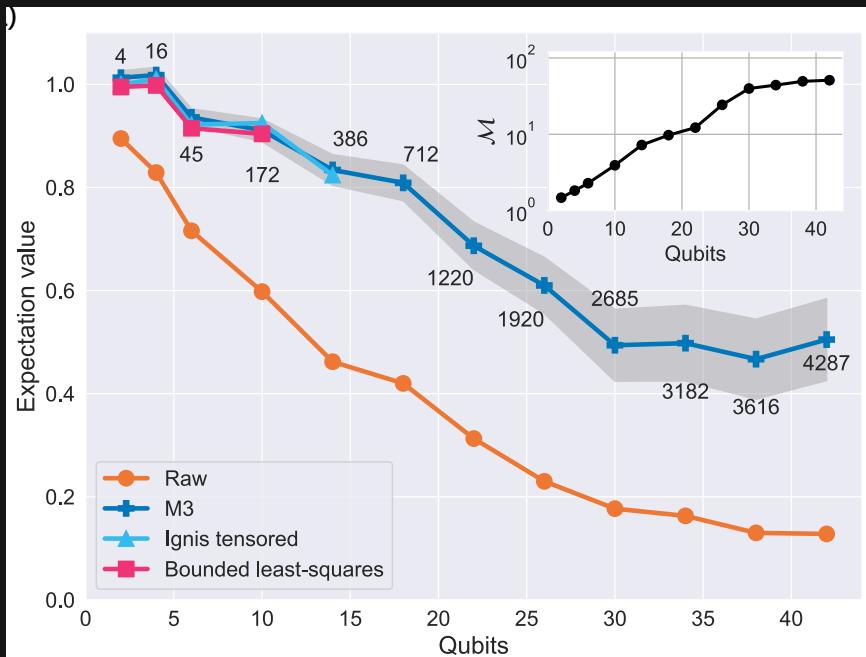
<https://arxiv.org/abs/2108.09197>

Scalability: Mitigation methods

Scalable measurement mitigation using reduced subspace and matrix-free iterative methods.

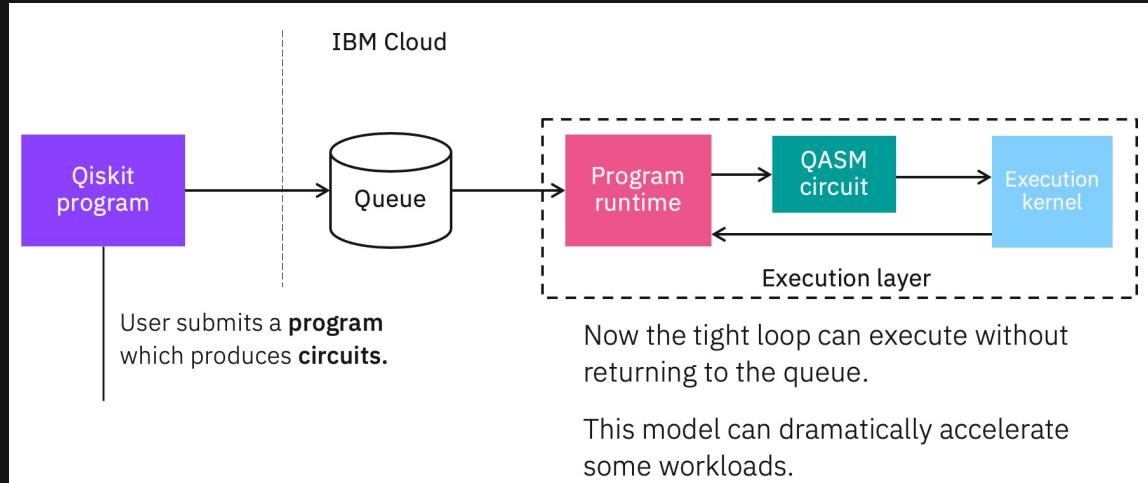
Can mitigate measurement errors out to numbers of qubits beyond the reach of even the largest supercomputers using a laptop.

Can be combined with similarly scalable gate error mitigation techniques.



<https://arxiv.org/abs/2108.12518>

Speed: Qiskit runtime



User submits entire program containing quantum + classical components to cloud.

Iterative hybrid algorithms operate with low latency connection to quantum hardware.

100x improvement in algorithms such as variational quantum eigensolvers.

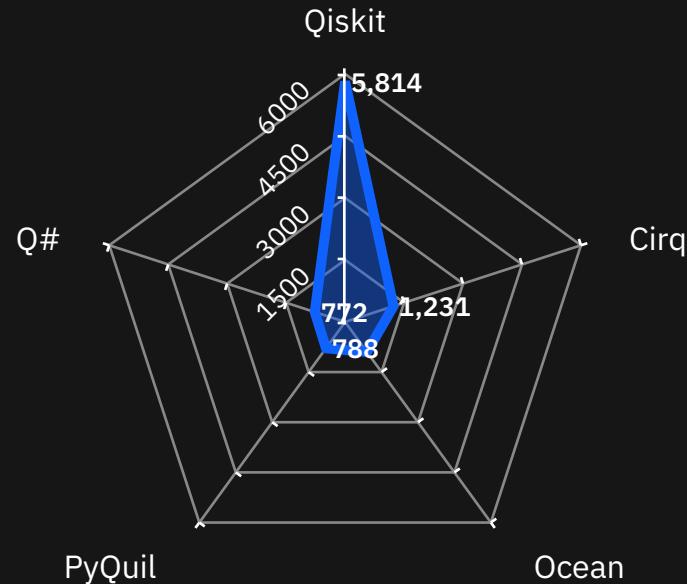
Adoption

Over **250,000** registered users on IBM Quantum platform.

Close to **700** papers published using IBM Quantum hardware and Qiskit.

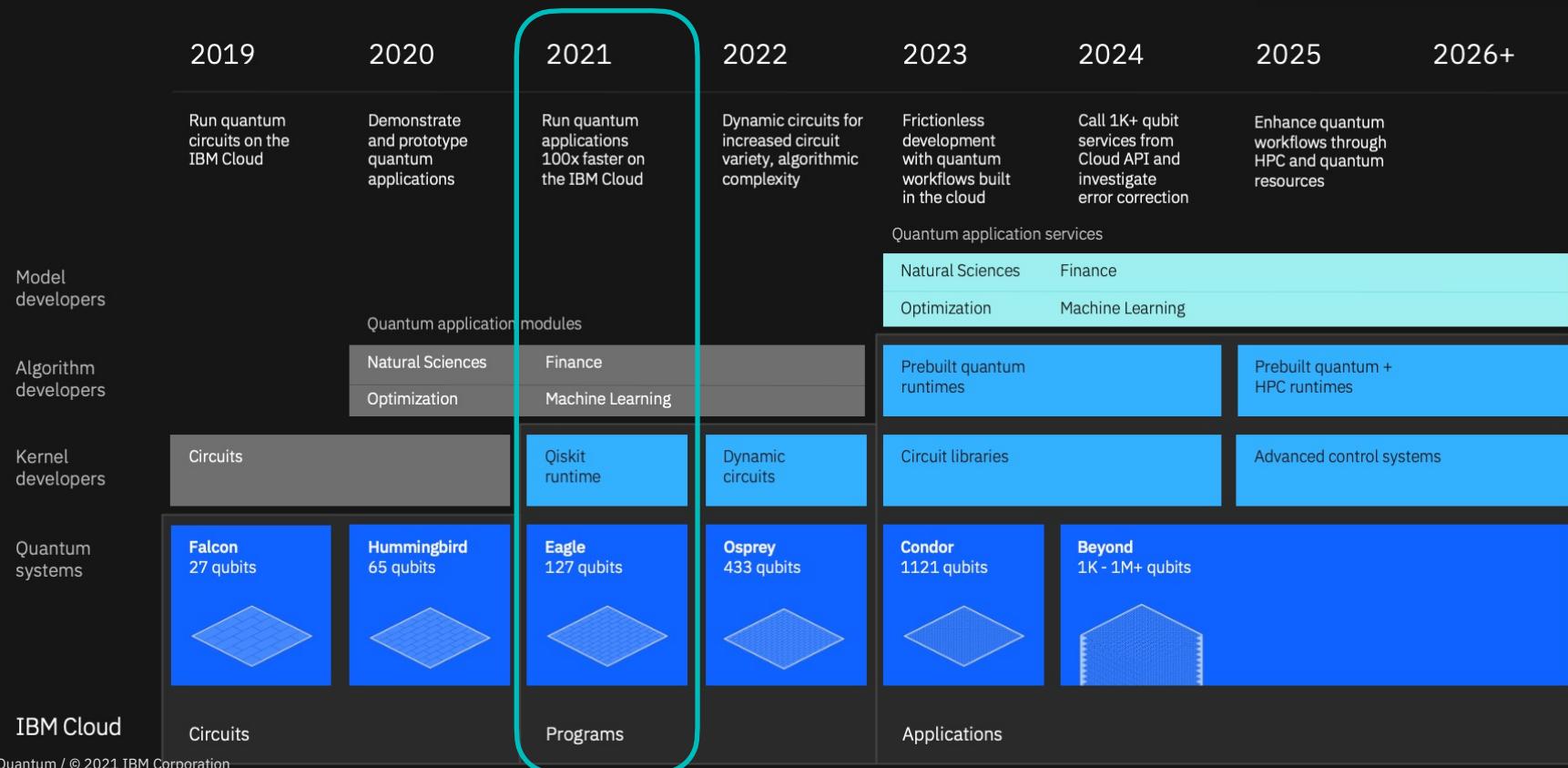
Over **150** members of the IBM Quantum Network.

Qiskit the most widely used quantum computing SDK on the planet.



Github Forks as of May 2021

Development roadmap



IBM Quantum