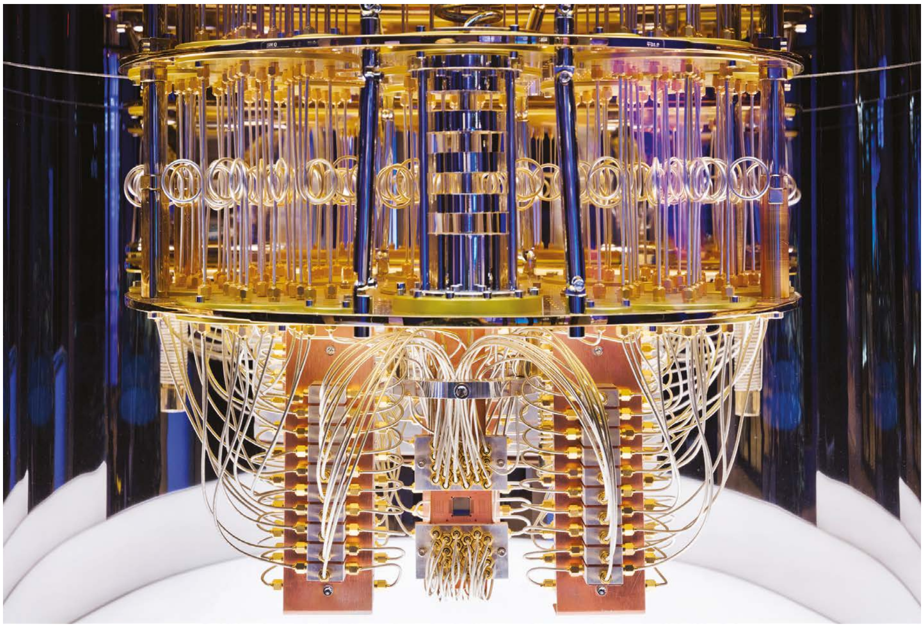

The innards of an IBM quantum computer show the cables used to control its qubits.

IBM

FIRST 100-QUBIT QUANTUM COMPUTER ENTERS CROWDED RACE

But IBM's latest quantum chip and its competitors face a long path towards making the machines useful.

By Philip Ball

IBM's newest quantum-computing chip, revealed on 15 November, established a milestone of sorts: it packs in 127 quantum bits (qubits), making it the first such device to reach 3 digits. But the achievement is only one stage in an aggressive agenda boosted by billions of dollars in investments across the industry.

The 'Eagle' chip is a step towards IBM's goal of creating a 433-qubit quantum processor next year, followed by one with 1,121 qubits, named Condor, by 2023. Such targets echo those that for decades the electronics industry has set itself for miniaturizing silicon chips, says Jerry Chow, head of IBM's experimental quantum-computing group at the Thomas J. Watson Research Center in Yorktown Heights, New York.

Other companies — including technology behemoths Google and Honeywell, and a slew of well-funded start-up companies — have similarly ambitious plans. Ultimately, they aim to make quantum computers capable of performing certain tasks that are out of reach of even the largest supercomputers that use classical technology.

"It's good to have ambitious goals, but what matters is whether they can execute their plans," says quantum information theorist John Preskill at the California Institute of Technology in Pasadena.

Quantum advantage

By exploiting the laws of quantum physics to process binary information, quantum-computing circuits such as the Eagle chip can already do calculations that can't easily be simulated on classical supercomputers. Google famously reported achieving such a 'quantum advantage' in 2019 (ref. 1), using qubits made, like IBM's, with superconducting loops. A team at the University of Science and Technology of China (USTC) in Hefei last year reported achieving quantum advantage using optical qubits[2]; this year, it did the same with superconducting qubits[3].

But the tasks these machines were given were artificial, researchers warn. "No experiment has demonstrated quantum advantage for practical tasks yet," says physicist Chao-Yang Lu, who co-led the USTC effort. Solving real-world problems such as simulating drug molecules or materials using quantum chemistry will require quantum computers to get drastically bigger and more powerful.

Quantum engineer Andrew Dzurak at the University of New South Wales in Sydney, Australia, thinks that with 1,000-qubit chips such as IBM's planned Condor, the technology might start to prove its worth. "But to do really paradigm-shifting stuff, you are going to need millions of physical qubits," he adds.

Chip challenges

The Eagle chip has almost twice as many qubits as IBM's previous flagship quantum circuit, the 65-qubit Hummingbird. The increase required the team to solve several engineering problems, says Chow. To enable each qubit to interact with several others, the researchers opted for an arrangement in which each is linked to two or three neighbours on a hexagonal grid. And to allow individual control of each qubit without an unmanageable tangle of wires, the team placed wires and other components on several stacked tiers.

But the processing power of a quantum circuit isn't just about how many qubits it has. It also depends on how fast they operate and on how resistant they are to errors that could scramble a calculation, due for example to random fluctuations. Chow says that there's still scope for improvement in all these respects for superconducting qubits.

Dealing with errors is particularly difficult, because the laws of physics prevent quantum computers from using the error-correcting methods of classical machines, which typically require keeping multiple copies of each bit. Instead, researchers aim to build 'logical qubits' — in which almost all errors can be identified and corrected — from complicated arrangements of many physical qubits. The procedures proposed so far typically demand that each logical qubit contain around 1,000 physical qubits, although that ratio depends on the intrinsic fidelity — the error-resistance — of the physical qubits, says Dzurak.

Beyond Condor-level devices, Chow says, circuit designs are likely to become modular, with several chips linked through "quantum interconnects". It's not yet clear how best to do that — perhaps with the microwave-frequency signals currently used for data input and output to superconducting qubits, or maybe by converting the quantum information to light-based signals. "It's an entirely new area of research," says Chow.

Many researchers think the first real-world applications of quantum computers are likely to be in relatively specialized fields, such as simulation of molecules and materials, machine learning and optimization problems in industries including finance. To get to that stage, "I expect we'll see gradual improvement in performance rather than a sudden leap forward", says Preskill. "It is likely to be a long slog before we can run useful applications."

1. Arute, F. *et al. Nature* **574**, 505–510 (2019).
2. Zhong, H. S. *et al. Science* **370**, 1460–1463 (2020).
3. Wu, Y. *et al. Phys. Rev. Lett.* **127**, 180501 (2021).