FOCAL POINT ON QUANTUM COMPUTING IN JAPAN

PRODUCED IN PARTNERSHIP WITH MOONSHOT RESEARCH AND DEVELOPMENT PROGRAM

EXPLORING MANY PATHS TO REALIZE QUANTUM COMPUTERS

Japan's ambitious MOONSHOT TO DEVELOP FAULT-TOLERANT COMPUTERS BY 2050 has a clear goal, but it remains uncertain which technology will win out.

The summit is clearly visible, but the path leading up the mountain is shrouded in mist. That's a picture of the sixth goal of the Japanese government's Moonshot Research and Development Program, namely the "realization of a fault-tolerant, universal quantum computer that will revolutionize the economy, industry, and security by 2050."

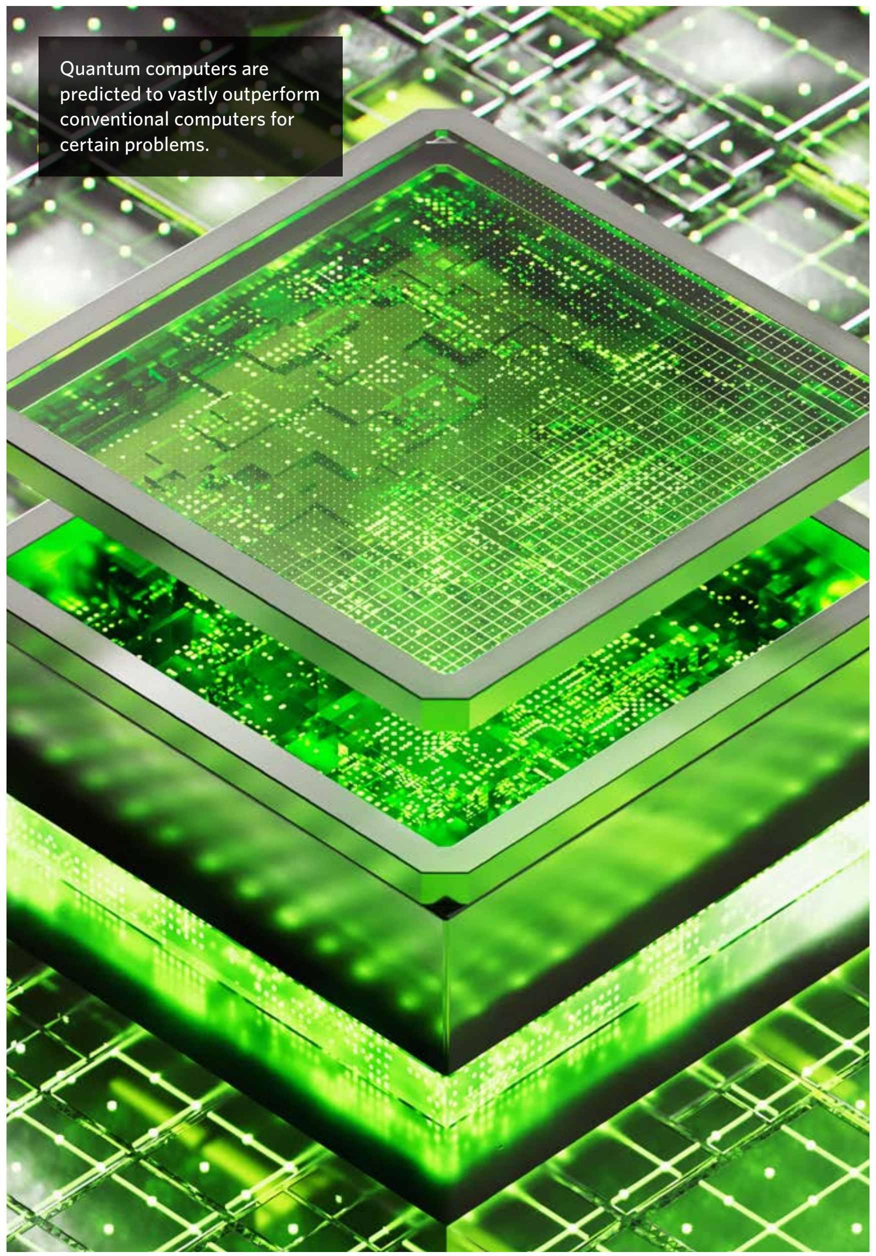
While all striving towards the same goal, the researchers participating in the programme have radically different opinions about the best technology for realizing quantum computers. But they all concur that when quantum computers do come online, they will have a transformative effect on society.

DISRUPTIVE POTENTIAL

"Quantum computers will help solve some of the toughest problems the world is facing," predicts Masahiro Kitagawa, director of the sixth goal of the Moonshot Program. "They're expected to unlock Nobel-prize-level discoveries in physics, chemistry and the life sciences, and they will power the financial sector."

Quantum computers will be a truly quantum leap, not just offering more computing grunt, but rather providing a completely different way of performing calculations that harnesses the mysterious properties of quantum objects such as superposition and entanglement. This will enable them to crack problems that lie well beyond the reach of even the most powerful computers available today.

"This Moonshot goal aims to realize quantum computers that can cause innovations in a variety of fields, and to shift towards a knowledge-intensive society," says Daisuke Kawakami, the deputy director general of the Japanese Government's Cabinet Office. "Our goal is to transform society."



Quantum computers are predicted to vastly outperform conventional computers for certain problems.

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The first superconducting qubit was **DEMONSTRATED IN JAPAN** in 1999.

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Researchers were given online access to the **FIRST DOMESTICALLY PRODUCED QUANTUM COMPUTER** in Japan in March 2023.

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MULTIPLE ROUTES

But while there is universal consensus about the disruptive potential of quantum computers, there are conflicting opinions about the best way to develop them. Five main platforms are currently being pursued for realizing quantum computers: superconductors, semiconductors, light, trapped ions and neutral atoms. As an indication of how open the field currently is, all five technologies are being explored by Moonshot projects.

"Nobody knows which platform will achieve fault-tolerant quantum computing," says Kitagawa, who is also a professor in quantum computing at Osaka University. "At this point, we don't even know which are the most promising."

Everything is up in the air. "The best platform could turn out to be a completely new one that hasn't been considered yet or a combination of different platforms might work the best," says Kitagawa. "One platform could lead for the first few decades, but later be overtaken by another one."

For Kitagawa, the most fascinating aspect of quantum computers is that they artificially create a large system that behaves quantum mechanically.

"We never see quantum phenomena such as superposition or entanglement, because in our macroscopic world, quantum states break very easily through interactions with their environment," says Kitagawa. "By artificially performing quantum error correction, we can counteract this degradation process and maintain a large system in a quantum state for as long as is needed to perform calculations. That's something remarkable, and it has never been achieved before."

Quantum computers effectively blur the boundary between the quantum and macroscopic worlds. "Previously, the boundary between quantum and classical worlds was probably around the molecule — anything bigger and the quantum nature becomes contaminated," says Kitagawa. "But by performing error correction that boundary will be dramatically shifted from the molecular level to a computer level."

SUMMER AGAIN

Japan got off to a flying start in the development of quantum computers with the demonstration of the world's first superconducting qubit — the building block of quantum computers — in 1999 by Yasunobu Nakamura and Tsai Jaw-Shen. They also realized two-qubit gates and quantum entanglement. "At that time, Japan was running ahead of the world," says Kitagawa.

But in the early 2010s, when big multinational companies such as Google and IBM entered the race to develop quantum computers, a 'quantum winter' set in in Japan.

"Japan had a quantum winter, and all the research money dried up," says Kitagawa. "Even Professor Nakamura couldn't get enough funding to continue his quantum computing research." Behind this funding cut was a feeling that fault-tolerant quantum computing was too hard to achieve.

The Moonshot thus represents a fresh optimism in Japan about the potential to realize fault-tolerant quantum computers and is ushering in a 'quantum summer'. The Moonshot goal of 2050 indicates that we're only a decade and a half away from realizing them.

The original moonshot — the race to the Moon in the 1960s — was once criticized for spending a lot of taxpayer's money while not providing many tangible benefits. The same criticism cannot be made of the Japanese government's nine Moonshot goals.

"In formulating these goals, the government has asked how technology and science can be used to realize human well-being," says Kawakami.

The goal of realizing fault-tolerant quantum computers promises to go a long way to delivering on this vision. But it requires the courage to set out into uncharted territory. ■

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JAPAN'S THIRD QUANTUM COMPUTER, WITH 64 QUBITS, WAS LAUNCHED IN DECEMBER 2023.

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"Nobody knows which platform will achieve fault-tolerant quantum computing."

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