

The Genesis Mission and the Future of the Future of Computing

The US Department of Energy's Genesis Mission aspires to accelerate an evolution in computing that can help the United States address national and global challenges faster. The initiative connects the expertise and resources of DOE's national laboratories with a consortium of the country's leading industry, academic, and philanthropic organizations. As a Genesis consortium member, IBM is contributing access to its hardware, software, and research across artificial intelligence and quantum computing. More importantly, IBM's involvement in Genesis provides its ecosystem of members and users across enterprises and universities with new opportunities to advance quantum-centric supercomputing. This combination of quantum, AI, and classical computing can soon be used to perform calculations beyond the ability of any single compute architecture, solving major hurdles in science that have previously strained classical-only systems.

This capacity has been a long time in the making. Quantum computing emerged in the 1960s and '70s from research studying the physics underlying computation itself. Both classical and quantum computers represent a unit of information as a string of binary digits. Systems computing classical information can only manipulate a single binary string at a time, while systems capable of computing quantum information assign amplitudes to every possible bitstring at once, and then use constructive and destructive interference to change the value of these amplitudes. At the end of the computation, called a quantum circuit, these amplitudes turn into probabilities used to determine a single bitstring output.

This form of computation provides a mathematical framework to create algorithms that would otherwise require exponentially more classical compute resources to tackle. Quantum algorithms have widespread applicability for problems across life sciences, energy, chemistry, machine learning, optimization and logistics, and more.

Since the first quantum algorithms emerged in the 1990s, companies around the world have attempted to build hardware capable of running them—in essence, devices that offer fine-tuned control over real or engineered atoms to recreate the mathematics of quantum mechanics. Among the most promising architectures are superconducting qubits: chips produced using similar processes to today's microchips but incorporating superconducting materials, which display quantum properties and conduct current without resistance. These chips must be kept isolated in dilution refrigerators at temperatures colder than deep space to maintain their quantum properties and reduce sources of noise.

IBM is collaborating with partners across the United States and around the world to realize the quantum-centric supercomputing framework capable of running these algorithms. In 2024, we installed an IBM Quantum System One on the campus of Rensselaer Polytechnic Institute (RPI) as part of the Curtis R. Priem Constellation. Together, we are researching closed-loop workflows across this system and RPI's Artificial Intelligence Multiprocessing Optimized System supercomputer. We are doing similar work alongside the RIKEN Center for Computational Science in Japan,

running workflows across an IBM Quantum System Two and the Fugaku system, ranked the ninth-largest supercomputer in the world.

These collaborations informed IBM's publication of a reference architecture for quantum-centric supercomputing, which describes how other high-performance computing centers can co-locate quantum computers and next-generation classical computers with open software and standard interfaces. The Genesis Mission offers an opportunity to test this approach at a national scale. DOE's national laboratories run some of the world's most capable supercomputers. IBM will bring quantum resources into that platform through access to our systems—open interfaces that let lab software use a quantum computer like any other system, and workflows co-designed with lab scientists. This integration will take years to build and prove, so the work must begin now.

Equally important is the ongoing work to discover new quantum algorithms and use cases. As a member of the Quantum Science Center (QSC) at Oak Ridge National Laboratory, IBM is contributing to research into quantum algorithms for hybrid quantum-classical systems that can be used to simulate materials. QSC is one of five National Quantum Information Science Research Centers created by the National Quantum Initiative Act of 2018. Each center is committed to solving problems across quantum hardware, software, and algorithms. (IBM is a member of four of the five centers.)

To further advance promising quantum-centric supercomputing applications in large-scale materials and molecular simulation, IBM Research scientists are also exploring a family of techniques called quantum diagonalization methods, which split computation problems across classical and quantum computers. In the spring of 2026, IBM, Cleveland Clinic, and RIKEN used these techniques to simulate a protein-ligand complex with over 12,000 atoms, the largest biologically meaningful molecular simulation performed with quantum hardware to date. The classical computing components were performed on the Fugaku supercomputer at RIKEN and the Miyabi-G supercomputer operated by the University of Tokyo and the University of Tsukuba.

Beyond these applications, there is broad agreement that hybrid compute is required simply to advance quantum computing. A project led by IBM researcher Kristan Temme to use large language models to search scientific literature to find problems that could benefit from existing quantum algorithms was selected as part of Genesis Mission's first request for applications. Other research uses AI models to find optimal error-correcting codes to advance fault-tolerant quantum computing. By 2029, IBM plans to deploy the first fault-tolerant quantum computer, called IBM Quantum Starling, which will be able to accurately run a hundred-

million quantum operations on 200 fault-tolerant qubits. We expect to further this research as part of our collaboration in the Genesis consortium.

Another example of how AI and quantum are interacting can be seen in recent work from IBM, Oak Ridge National Lab, and a consortium of partners on one of the Genesis Mission's key interests: nuclear fusion. Together, we studied the composition of molten salts lining the inside of a tokamak reactor to optimize the generation of tritium fuel necessary for nuclear fusion, using up to 64 qubits and 2,654 two-qubit gates. The quantum-centric calculation matched leading classical methods without the simplifications such calculations usually require. In this case, researchers employed AI agents to study 70 years' worth of experimental data on molten salts and propose specific candidates to be explored further with quantum-centric supercomputing. AI is also helping to uncover the thermal properties of these materials.

All told, the Genesis Mission clarifies the nation's aims for the future of computing: to accelerate scientific discovery and solve the world's hardest problems by building a single compute framework combining the latest hardware, software, and algorithms across classical, quantum, and AI.

We hope that Genesis will further define quantum's role in a quantum-centric supercomputing workflow; that the large-scale integration of resources can yield great strides in using AI to mature error correction; and that the design and implementation of quantum-centric supercomputing algorithms will indeed achieve the initiative's goals to "accelerate discovery science, strengthen national security, and drive energy innovation." We are eager to see this translate to real wins for more Americans.

The mission closely aligns with IBM's vision. IBM has been a leader in quantum computing since the field's inception. IBM fellow and information theorist Charlie Bennett helped devise the mathematical basis for quantum, and theoretical physicist David DiVincenzo outlined the five minimum requirements for creating a quantum computer while working as a researcher at IBM. IBM was the very first to put a quantum computer on the cloud for anyone to program. The company has deployed over 90 systems and maintains a fleet of processors with over 100 qubits capable of running up to 7,500 quantum operations each. And it was at an IBM-sponsored conference in 1981 that physicist Richard Feynman argued that "nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy."

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