Quantum Computer Project

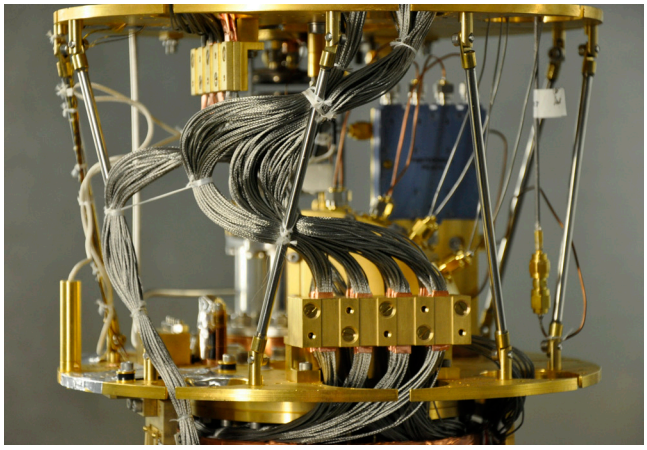
Accelerating Advanced Computing

NASA's quantum computing project is an experiment to assess the potential of quantum computers to perform calculations that are difficult or impossible using conventional supercomputers. The project is a collaboration among teams at NASA, Google, and the Universities Space Research Association (USRA).

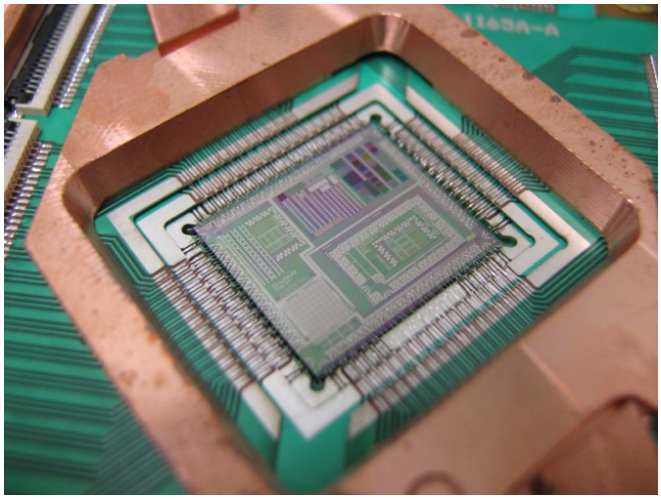
The NASA team aims to demonstrate that quantum computing and quantum algorithms may someday dramatically improve the agency's ability to solve difficult optimization problems for aeronautics, Earth and space sciences, and space exploration missions.

Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer.

Engineers are installing a D-Wave Two™ quantum computer in the new Quantum Artificial Intelligence Laboratory (QuAIL) located in the NASA Advanced Supercomputing (NAS) facility at NASA's Ames Research Center, Moffett Field, Calif. The system—



Support structure for installation of the D-Wave Vesuvius processor.



The D-Wave superconducting 512-qubit Vesuvius processor chip.

about the size of a garden storage shed—is housed inside a cryogenics system within a 10-square-meter shielded room. It will be the most powerful in the world, with approximately 512 superconducting flux qubits. The installation team will put the system through a series of rigorous calibration and acceptance tests, and operations are planned to begin in early fall 2013.

Once the quantum computer is operational, researchers at NASA Ames and other NASA centers will use it to investigate quantum approaches to optimization problems in air traffic control, autonomy, robotics, navigation and communication, system diagnostics, pattern recognition, anomaly detection, and mission planning and scheduling. Through testing of problems in these disciplines, NASA's quantum computing team hopes to demonstrate that large-scale quantum computers will be able to solve certain problems much faster than any classical computer using the best currently known optimization algorithms.

One initial application will be related to the NASA Kepler mission's search for habitable, Earth-sized planets. The complex computational task of identifying and validating the transit signals of smaller planets as they orbit their host stars is currently based on heuristic algorithms (designed to find approximate solutions when classic methods don't find exact

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solutions), implying that some planets could remain undiscovered due to this computational limitation. Using a quantum computer to perform Kepler's data-intensive search for transiting planets among the more than 150,000 stars in the spacecraft's field of view has the potential to provide a unique, complementary approach to the task of discovering potential new Earth-like exoplanets.

Another early application will be in the area of planning and scheduling. Determining the very best use of limited resources during space missions—such as time and power—can require hours, days, or even weeks to solve with classical algorithms. Automated planners have their origins in robotics and have been used extensively in space applications. Examples of such applications developed at NASA Ames include automated planners for the ongoing Mars Curiosity mission and software that helps optimize operations of the International Space Station's solar arrays. NASA researchers are mapping planning problems from a variety of areas, including planetary rover exploration, to forms suitable to be run on quantum computing systems.

In addition, the broader academic community, through USRA, will be able to utilize the D-Wave Two system and conduct collaborative research on the benefits of quantum computing together with researchers at both NASA and Google.

Through a five-year, non-reimbursable Space Act Agreement between NASA, Google, and USRA, the project team will conduct four main technology tasks: quantum computer acceptance tests; development of quantum AI algorithms and mapping onto the system; development of problem decomposition and hardware embedding techniques; and creating quantum-classical hybrid algorithms.

Over the next months and years, the results of NASA's exploration into the potential of quantum computing methods will be highlighted in peer-reviewed journals and research blogs. The hope is that quantum computing will vastly improve a wide range of tasks that can lead to new discoveries and technologies that may significantly change the way we solve real-world problems.

Flight controllers at the PHALCON (Power, Heating, Articulation, Lighting Control Officer) console at NASA's Mission Control Center at Johnson Space Center manage the electricity available to operate the International Space Station systems and experiments.

For more information about the quantum computer, visit:

http://www.nas.nasa.gov/quantum

For more information about NASA's partnership with Google and USRA, visit:

googleresearch.blogspot.com/2013/05/launching-quantum-artificial.html

http://www.usra.edu/quantum/

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