National Aeronautics and
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Committee on Science, Space, and Technology

U.S. House of Representatives

Statement by:

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Statement of
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Chairman Lucas, Ranking Member Lofgren, and distinguished Members of the Committee, thank you for the opportunity to appear today to discuss NASA's role in quantum research and development. I look forward to discussing the revolutionary potential of quantum technology, highlighting some of the NASA work in this area, and giving you my perspective on potential future activity.

Introduction

I direct the Quantum Artificial Intelligence Laboratory (QuAIL) at NASA Ames Research Center, in the heart of Silicon Valley in California. Our team focuses on quantum computing research and collaborates closely with groups at other NASA Centers on quantum networking and quantum sensing. The mandate of the QuAIL team is to determine and advance the potential for quantum computing to enable more ambitious and safer NASA missions in the future. I joined NASA just over a decade ago to help build its quantum computing effort.

Background

Quantum information science draws on the principles of quantum physics, the physics of the microscopic realm, and information theory to understand and harness the unique properties of quantum systems to process information in powerful ways. The applications of quantum information science and technology (QIST) range from computing and networking to measurement, timing, and remote sensing. Potential NASA applications range from astronomical imaging to the mapping of planetary electromagnetic and gravitational fields, to aeronautics, communications and navigation, as well as probing the deepest mysteries of the universe.

NASA works in all areas of QIST, including quantum computing, quantum networking, and quantum sensing. QIST promises unparalleled sensing precision, computational speed, and data transmission. QIST will have payoffs for our major objectives and programs including our Artemis and Moon to Mars programs, our climate science priorities, National Academies-driven Decadal science recommendations, large observatory programs, and data processing throughout the Agency. QIST is a current and future strategic capability for our aeronautics, Earth and space science, and space exploration programs.

Quantum Computing

When the QuAIL team at NASA Ames was formed just over 10 years ago, it followed the model of NASA's Advanced Supercomputing program; it would not build quantum computing hardware, but rather form close partnerships with groups that did. NASA's High-End Computing Capability (HECC) has long served as beta testers, or even alpha or pre-alpha testers, for supercomputing hardware and software. NASA QuAIL is a recognized as a leader in QIST, publishing widely.

Algorithmic work is essential for the ultimate utility of the field. Current prototype quantum processors are small and non-robust, but progress is rapid and, as the hardware advances, we will be able to explore quantum algorithms in ways impossible today. NASA, with its many computational challenges in aeronautics, Earth and space science, and space exploration, is a rich source for use cases. As a few examples, we have mapped out use cases applying quantum optimization for enhancing availability of communication in future air traffic management, quantum machine learning for image processing of wildfire data, and quantum artificial intelligence for space exploration planning and scheduling.

Quantum computing holds the promise of addressing challenges that today's high-performance computing cannot. In addition, today's high-performance computing resources are already stretched thin, given their high demand.

Quantum Networking

Advances in the technology required to generate and detect non-classical states of light, or quantum optics, have enabled the potential for new communications and networking technologies and protocols, both terrestrial and space-based. Potential applications for quantum communications include advances in communication security, data transfer, and space navigation in space-to-ground and deep space communication networks. Quantum networking is a critical technology required to link terrestrial quantum computers and quantum information systems through terrestrial and space data links.

NASA has been investigating how optical communications – using lasers, rather than radio frequencies – can enable quantum communications. NASA's Space Communications and Navigation program has conducted multiple successful technology-demonstration missions to develop this technology in the last ten years, and more are planned for the future, including: Deep Space Optical Communications (DSOC), Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T), and Orion Artemis II Optical Communications System (O2O).

SCaN is partnering with other U.S. Government agencies to research and develop capabilities in QIST, including in areas of advanced adaptive optics for ground stations, space-qualifiable quantum sources, detectors, and memory, as well as to develop quantum use cases and applications, including for quantum computing, networking, and sensing. These joint activities have produced mission concepts that include a space-based quantum-communication testbed. Since 2019, NASA has been actively supporting the National Science and Technology Council through membership in its two quantum subcommittees and in a number of interagency working groups within these subcommittees.

Quantum Sensing

Quantum sensing uses quantum properties of matter and light – such as quantum superposition and entanglement – to achieve unprecedented measurement sensitivity and performance that outperform their classical counterparts. Quantum sensors can impact technologies important for a range of NASA missions, such as timing, remote sensing, *in situ* measurements, metrology, fundamental physics, interferometry, communication, ranging, imaging, lidar receivers, and gravity measurements.

As an example, improving gravitational mapping would enable scientists to better understand the movement and change of ice, oceans, and land water on Earth. The Gravity Recovery and Climate Experiment (GRACE) and Follow-On (GRACE-FO) missions, through a set of twin trailing Earthorbiting satellites, have been mapping Earth's gravitational fields using microwave ranging instruments, a classical sensing technique, for over 20 years. Their current resolution is limited to 300 km. A future Quantum Gravity Gradiometer or QGG that uses the interference of laser-cooled atoms, a quantum sensing technique, could provide ten times better resolution mass-change data. NASA has funded development efforts toward demonstrating QGG for spaceborne Earth system mass change measurements.

Additionally, navigation and timing in space, and in areas in which the Global Positioning System (GPS) is unreliable or unavailable, is possible with quantum sensing technologies such as atomic clocks and atomic inertial measurement units. Finally, quantum sensing technologies can revolutionize NASA's science mission to unlock the secrets of the universe, enabling measurements that provide insight into fundamental questions such as the nature of dark matter and dark energy, gravitational wave astronomy, and the connections between quantum mechanics and gravity.

In the area of fundamental physics, NASA began work on the Cold Atom Laboratory (CAL) more than a decade ago, and CAL has been operating continuously on the International Space Station (ISS) since 2018. CAL routinely produces some of the coldest matter in the universe, probes the heart of quantum science in the microgravity of orbit, and serves as a pathfinder for future space technologies, including atom interferometery.

NASA's fundamental physics portfolio includes projects that seek to probe the nature of dark matter, dark energy, other physics beyond the Standard model, and look to reconcile the two titans of modern physics, quantum mechanics and general relativity, which are currently incompatible. They involve space-based or microgravity drop tower experiments in atom interferometry, ultra-cold atoms, atomic clocks, and entanglement – all pathfinders for the future applications as previously discussed.

Partnerships

NASA has ongoing, joint studies and activities with a number of QIST research groups in academia and industry. The QuAIL team has multiple partnerships over the years in quantum computing with industry, other Government organizations, academic institutions, and international entities. For example, with Google we have had multiple collaborations, going back to the start of the lab, including working as part of the team that supported Google's well-publicized demonstration of quantum supremacy in 2019 and as part of the team on their recent updated demonstration in April of this year. A successful demonstration of "quantum supremacy," or "quantum advantage," means that quantum processors have been able to do one, not necessarily very useful, thing that can't be done in a reasonable amount of time on even the largest supercomputers.

NASA has partnered, or is currently partnering, with Rigetti, NTT Research, with other Government agencies including the Defense Advanced Research Projects Agency (DARPA), the Air Force Research Laboratory, Department of Energy (DOE) laboratories, and academic institutions such as the Massachusetts Institute of Technology, Stanford, and University of California - Berkeley. We have formal international agreements with the German Aerospace Center, and the University of New South Wales in relation to the Australian Research Council Centre of Excellence for Quantum Computation and Communication Technology. In addition, we have informal collaborations with a wide variety of groups across the United States. NASA is also partnering with the Department of Homeland Security on QIST-related studies and projects. The National Quantum Initiative Act has inspired many new partnerships, building bridges between institutions that were not working closely together previously.

Conclusion

NASA has been the front runner in many technologies. I am personally inspired by the then-Director of NASA Ames Research Center, Hans Mark, bringing the Illiac IV – the first "massively parallel" computer – to NASA Ames in 1972, asking NASA researchers to demonstrate the potential of massively parallel computing. We are excited to play a similar role in the emerging area of QIST. As we look to the future and to a NASA in the 2040s, we envision quantum technologies permeating multiple missions and accelerating our knowledge of our world and the universe.

Thank you once again for allowing me to share my expertise in this area with you. I would also like to thank this Committee for its continued support of NASA's research. I would be pleased to respond to any questions the Members of the Committee may have.