There will be numerous technological advances and other benefits to the country from a sustained initiative, Aguiar agrees.

Aguiar gives as an example of his own scientific research in cryo-TEM, or cryogenic tansmission electron microscopy. This extremely low-temperature method allows researchers to work at the atomistic level, and to examine and manipulate phenomena such as electron spin states that are for quantum computing and other quantum technologies.

Working at very low temperatures adds to cost and equipment size, Aguiar says, and so researchers want to find ways to do this work at the atomic level at higher temperatures. Many other physics and materials science problems will benefit from these breakthroughs, he says.

Of quantum computers that exist today, Aguiar says, "We have them; they are really large and require a lot of cooling. We want to scale that technology down."

The NQI Act will also provide the funds needed to upgrade some of the country's major scientific user facilities, for example, the beamlines at Argonne National Laboratory that are used to study materials and problems across a range of disciplines. Upgraded scientific user facilities also mean jobs, Aguiar says. "We want really skilled technicians who can work with researchers, perhaps in addition to their own research. There would be hiring at all levels."

The NQI Act will enhance existing federal programs to support quantum research, such as the Quantum Leap program at the National Science Foundation (NSF), says Fil Bartoli, Division Director for the Division of Electrical, Communications and Cyber Systems. Quantum Leap was one of NSF's 10 Big Ideas for Future Investment identified by NSF in 2016. It is a $30 million per year, multipronged effort to advance fundamental understanding of quantum phenomena, materials, communications, and systems, Bartoli says. The agency plans to announce new funding opportunities under the program this year.

Materials science will be a "veritable treasure mine," Bartoli says. "The materials division at NSF is heavily involved."

"A lot of materials questions will have to be answered," Bartoli says, that will bring together research on superconducting materials, trapped ion technologies, and neutral ion vacancies, for example.

As Quantum Leap and the NQI Act get rolling, "there are going to be quite a few opportunities to have a big impact on society," Bartoli says.

William G. Schulz

CSIRO looks to space industry to support "lunar" challenge

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The latest industry roadmap published by CSIRO, Australia's national science agency, encourages the growing Australian space sector to join with international partners to provide technological expertise to help to establish a human base on the Moon. According to Megan Clark, head of the Australian Space Agency, the agency is mandated to grow the size of the domestic space industry to $12 billion by 2030.

According to CSIRO, meeting the "lunar" challenge would involve building capabilities in autonomous robotic systems, *in situ* resource utilization, habitat and life support, and power and propulsion. Deep-space exploration missions are hostile environments for humans, so developments in machine learning, artificial intelligence, and robotics are essential to gather data and supporting analytics. To support habitat and life on the Moon, the development of innovative systems will be needed to provide food, medicine, shelter, and waste management.

Use of local resources at the exploration destination may require mapping and prospecting, processing of new minerals and materials, and additive manufacturing capabilities, according to the roadmap. Furthermore, technology solutions suitable for *in situ* power generation, energy harvesting and storage, engine and fuel options for rockets, and in-space propulsion will be needed.

An international coordination group already exists with the aim of expanding human exploration and presence in low Earth orbit, and on the Moon and Mars, over the next two decades. Australian space sector support for the lunar challenge would be an opportunity to grow these existing relationships with global partners, including international space agencies.

Launched in September by the Minister for Industry, Science and Technology, Karen Andrews, at the 18th Australian Space Research Conference, the report—"Space: A Roadmap for Unlocking Future Growth Opportunities for Australia"—highlights Australia's unique strengths and geographic advantages to increase the country's share of the international space sector.

The new roadmap was developed by CSIRO Futures, the strategic advisory arm of CSIRO, following extensive industry consultation with nearly 150 business, government, and technology representatives.

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https://doi.org/10.1557/mrs.2018.270 Published online by Cambridge University Press