Input to the Queensland Government Space Review
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## Executive Summary

Australia's new space agency provides an opportunity for Australia to bring its unique capabilities to the global space exploration community. Leveraging Australia's ingenuity in adapting to a harsh, remote environment, Australia should adapt remote asset management, autonomy, and manufacturing capabilities from industry, academia and government for microgravity and the lunar environment.

I propose that Australia set up an institute for remote asset management, mining, manufacturing and maintenance in extreme environments. The institute would be accountable to drive progress in bringing the technological achievements in Australia's industry to bear in the space community and enable cross flow of space technology back into those industries. Queensland could play a critical role in this institute, serving as the hub for robotics, trusted autonomy, and advanced field manufacturing. The goal is for Australia to become the provider of remote asset management technologies for future international lunar exploration, which is expected to develop over the next ten years.

## Introduction

Australia's new space agency heralds a tremendous economic opportunity for the country. The space agency has selected several areas of interest where existing capabilities can be effectively orchestrated to generate a robust entry into the global space market – communications, space surveillance and debris mitigation, and use of space-based earth observation and the internet of things for multiple industries. These are all excellent near-term opportunities that should be vigorously pursued.

However, it's also important to look out across a longer time horizon for strategic capabilities that Australia can bring to future large international space exploration projects. These international projects are enormously important for long-term strategic government partnerships, and, more recently, creating positioning for future markets. The current example is the International Space Station. Each partner brings a piece to the table, and then gets access to the science and technology of the whole facility, and the inspiration for their students. Even more importantly, each country's industry interacts and work with industry from other countries also supporting the project, generating partnerships that help them enter the global supply chain. These benefits magnify the impact of each individual country's investment. Because NASA and other large agencies require critical capability such as launches to deliver supplies and experiments, Australia does not need to build its own heavy lift capability to engage. This will come as a natural part of the partnership. There are many other examples of capabilities that will come "for free" with the partnership but deep space launch is among the most important.

For commercial space industry, a space demonstration is the key milestone needed for investors and results in a step change in valuation. Being able to send payloads or CubeSats to the station has benefited multiple successful startup companies such as Planet and Made in Space. International focus has sharpened around accelerating the pipeline from space exploration demonstration to commercialization. This is the right time for Australians to bring the ingenuity they have brought to operating in remote, harsh environments to bear in the next international steps planned to the Moon and on to Mars.

The benefits beyond the space industry are evident. The technology and systems integration required to run a remote un-crewed offshore facility, an autonomous mine, or distributed power networks are identical to those required to run a normally uncrewed space station or lunar outpost. Australia already has many assets being remotely operated and is actively pushing the boundaries of what can be achieved remotely in terms of complexity of operations, manufacturing and maintenance. Woodside Energy's relationship with NASA Johnson Space Center as well as Chevron's relationship with the Jet Propulsion Laboratory are two examples of the proven value of collaboration across industries. An institute would accelerate knowledge transfer from space to ground industries and ground to space industries, bringing immediate benefit to member industry partners. Industry would also benefit in terms of hiring talent. For example, many of the best and brightest in the space community would not currently even think to look to the resources sector for opportunities. Importantly, all industries will require the TAFE systems to provide an ever-increasing number of technicians who can work to replace, repair and upgrade the sensors, communication infrastructure, robotics and automation equipment. Based on the findings of the Expert Reference Group whose findings drove the formation of the space agency, Australians overwhelmingly support engaging in space. Australian participation in lunar exploration would be a truly exciting goal and will provide the focus for inspiration in the student pipeline to study in STEM fields.

The specifics of future international efforts in space is still dynamic, but NASA has committed to building a Lunar Orbiting Platform Gateway (LOPG) which will serve as a logistics depot and transfer point to the lunar surface. The acquisition solicitation for the propulsion node of the LOPG has already been released. This platform will be human tended – meaning that it will not be permanently crewed, but that crews will spend time and transition through. NASA has also publicly stated that it is seeking international and commercial partnerships for the lunar lander element. The European Space Agency (ESA) has proposed a "Moon Village" arrangement where each country develops a ground segment on the lunar surface but with shared infrastructure between countries. These enterprises will require major technology investments to achieve and will come to fruition in the next 10 to 15 years.

Australia is positioned to provide remote asset management capabilities to both the orbiting platform LOPG and to the surface element. In-situ Resource Utilization (ISRU) will also be needed - excavation of lunar regolith for manufacturing material and to extract water for rocket propellant. ISRU includes the ability to field manufacture material for construction and for maintenance from readily available materials. It is critical for a sustainable presence on the Moon, and to prepare for Mars exploration. Australia's autonomous mining and advanced manufacturing technologies could be successfully applied to ISRU and to support economically viable mining for rare earth metals which are abundant on the Moon. Importantly, no other country is looking to own this technology space, so efforts now could result in a technological and economic leadership role for Australia. Although 10 to 15 years may seem a long way away, in fact the planning is occurring now. Small investments are needed immediately to begin building the capability in time to deliver to the project, with steady growth proportionate to success.

**Institute for Remote Asset Management, Manufacturing and Maintenance in Extreme Environments**

Although remote asset management and autonomous mining are developed capabilities in Australia, adapting them to space requires additional technical and policy work. Aspects of remote asset management to include schedule planning, individual autonomous tasks, and data mining for trend analysis are all currently being used and explored in the space domain on the International Space Station (ISS), but the Lunar Orbiting Platform Gateway will need to have a much more integrated and robust capability. Since crews will not be present full time but will be transitioning through and spending

periods of time there, the LOPG must be capable of being operated by humans as well as remotely managed when no crew is present. Even today juggling the logistics challenges of multiple delivery vehicles, each with differing constraints, absorbs considerable resources.

The excellent news is that not only does Australian industry have substantial capability, there is also significant research being undertaken that can be leveraged (for example, the current work that Woodside is doing with NASA on task autonomy through robotics). **We propose an Institute for Remote Asset Management, Manufacturing and Maintenance in Extreme Environments to bring together existing capabilities with the research and development needed to transition the technologies to the space domain (as well as potentially other extreme environments). This institute would be a consortium of industry, government, and academia to advance the technologies and promote the cross-flow of space technologies and resources technologies.**

The government is absolutely necessary as a partner. At the federal level, the Australian Space Agency will be the entity that promotes Australian capability to international partners and puts the proper agreements in place to develop, test, and field the capability in space. The ISS, LOPG, and potentially commercial Low Earth Orbit space stations being considered for the future are all excellent places to demonstrate and refine remote asset management technologies.

The Queensland state government can provide continuity and connections for the community, support field demonstrations for technology spin-offs on earth, and support emerging businesses. Academia provides outstanding knowledge of the space environment from a scientific viewpoint, and the research and development needed to adapt technologies to space. Industry, however, is the essential centerpiece. Industry participation is vital to ensure that the capabilities created will be viable commercially both near term and in the future as a part of the global space industry.

To engage the resources industry and other sectors more broadly, the value must have a shorter-term outcome than 10 to 15 years down the road. Fortunately, there are substantial near-term benefits that should be of interest to industry; specifically, cross-flow of technologies that can unlock latent capability in systems that are already operating.

Examples of significant cross-flow potential (to name a few) include;

- human health and safety practices
- human and machine protection in extreme environments
- model-based system engineering and the creation of a digital twin for a complex systems
- robotics and automation
- light weight and power-efficient sensors and sensor architectures
- energy storage and distribution technologies;
- the ability to field manufacture equipment
- Robust, adaptable systems integration and networking
- Robust, redundant and self-healing communication

All of these capability threads that will need to be pursued to enable remote asset management, manufacturing, maintenance and autonomous mining on the Moon and in lunar orbit will have near-

term spinoff benefits to resources industries. The resources sector and other industries must be engaged to ensure that the most urgent relevant problems are being addressed.

Another major outcome from technology cross-flow is the potential to smooth out the cyclical nature of both the space and resources industry to allow cross-flow of people when one industry experiences a down-turn. A great example of this is that when the Space Shuttle program ended many engineers in Houston left the space industry for the oil and gas sector. When the oil and gas sector experienced historically low prices and the space industry was picking up, there was a migration back into space.

Governance models are of critical importance. Industry must bring resources to the table; otherwise, the federal government (specifically the Australian Space Agency, tasked with economic development of industry) will have no reason to invest. The International Centre for Radio Astronomy has a model that includes federal and state funding as well as multiple universities. Extending such a model to industry, and building a commercialization element into the governance, could be a new and creative model for how to enable the dissemination of new knowledge generated by academia into industry. The venture capital and incubator community must be engaged to as well. Each of the technology areas will also need an educational component – not just of PhDs, but also of technicians capable of servicing and supporting enabling technologies in industry. Finally, this must be a whole-of-Australia effort. Although individual states each have strengths, there is key expertise that exists in all states and territories that must be leveraged if Australia is going to be able to earn its seat at the table of the international space community.

Although remote asset management is an existing technology in the resources industries, the technology would have to be adapted to the space domain. Autonomous extraction of in-situ resources on the Moon will be needed later – however, it is a powerful and technology-driving goal.

The Role of Queensland

Queensland has many existing organizations with capabilities that can contribute to this national effort. Specifically these:

- QUT A Centre for Robotic Vision
- Autonomous Port Operations
- Advanced Robotic Manufacturing
- Defence CRC – Trusted Autonomous Systems
- CSIRO Queensland Centre for Advanced Technologies – Sensors, Communication, Underground Autonomous Mining
- Boeing Centre for Autonomous Vehicles

In-situ resource utilization and manufacturing tools and equipment in the field is a major need for a lightly-tended facility both here on earth and in space with likely similar needs. The convergence of additive manufacturing, modular design and robotics can bring this capability to industry today and to space in the future. Along with trusted autonomy, these capabilities can provide significant capability to defence, as well.

**National Approach**

The requirement of a collaborative national approach cannot be overstated. Australia does not and will never have the population of Europe or the spending capacity of NASA. A strong culture of collaboration, openness and inclusiveness will be key to the success of the vision of a significant Australian contribution to humanity's exploration while at the same time bringing immediate benefits to Australia's industry sector.

**Conclusion**

Exploratory discussions with industry and academia have been positive. The Australian Space Agency may be able to assist as well, but they have been clear that this effort needs to be self-organized. With partnerships and funding in place, the Australian Space Agency will need to know exactly what piece is missing that the federal government can provide.

Efforts must be made to identify champions and thought leaders and identify existing work and pockets of funding that could be brought together to create the Institute. With 10 to 15 years ahead, it will be acceptable to start fairly small and focus on near term spinoffs that benefit industry and generate enthusiasm. Many Australians are seeking a strong and powerful goal in space that will inspire future students and create national pride in something Australia does well. Near term economic development is simply not filling this need, but lunar exploration most certainly could and would. With a significant enough commitment to joint activities on the part of Australia, major science benefits and even the possibility of an Australian on the Moon are possible. The long-term potential is for key Australian capabilities to transfer to the space domain and bring new economic benefits and international leadership to Australia, and Queensland is well-positioned to take a central role.

**Disclaimer**

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