Australia in Space: a strategic plan for Australian space science

Planetary Sciences Working Group report

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Vision Statement

Australia has a world-class planetary science community, with expertise across all areas of the field, from the early solar system, to astrobiology, to comparative planetology. Early researchers like Stuart Ross Taylor, John Lovering, John Jaeger, Alfred Ringwood, Malcolm Walter and John de Laeter helped define the field internationally, and laid the foundation for Australia's recognised strength in sample analysis, synthesis and modelling. Our researchers are members of science teams on multiple missions currently led by other nations, evidencing the continued international standing of our community.

Planetary science is essential to solar system exploration, and missions are a key enabling capability for the field. Our vision for 2030 is to see Australia become an equal partner in the global community of space-faring nations by:

1. Leading our own planetary missions, with Australian-led science teams, and Australian-built payloads and spacecraft systems.
2. Contributing Australian hardware, software and scientific expertise to the most significant international space missions.
3. Creating a stronger foundation for Australian-led missions and contributions through education, innovative experimental work, sample analysis, field studies, and modelling relevant to planetary bodies.
4. Creating a world-class workforce of planetary scientists and spacecraft engineers, trained on missions, to feed a burgeoning industry and research sector, and act as ambassadors for our nation as we engage with other agencies.

Adding a sovereign capability in solar system exploration to our world-leading research skill-set would allow Australian planetary researchers to expand their horizons in terms of the range of science questions that they can address. Our planetary scientists have built, over decades, relationships with partner agencies overseas. Working together on shared missions would deepen and strengthen those relationships. By contributing payloads in addition to intellectual expertise we would be partnering on an equal footing, participating in the definition of mission goals.

Australian research leadership will generate innovations that will improve the lives of Australians across the board. Blue sky planetary science has transformed our understanding of the Earth, with benefits in the management of scarce resources, mining, and knowledge of climate change. A strong research base will close the virtuous circle of science underpinning innovation and economic growth in the sector; growth that then feeds back into increased private sector funding for science. It will define for the first time an education program and career path for Australian science and engineering students, through university, working on projects with partner agencies, and then on to industry. But more than anything, a sovereign capability in solar system exploration would inspire Australians.

2030 will see a flourishing Australian planetary science community, with excellence in ground-based research, complemented and energised by a mature capability in planetary missions. Australian science teams will be exploring the solar system with Australian spacecraft and payload contributions.

We will leverage key strengths in sample analysis, astrobiology, Martian and Lunar geology, geophysical modelling, and solar system formation, to develop world-leading programs that combine ground-based and space-based scientific exploration. In addition to a planetary science research base, our geoscientists are recognised for world-leading expertise relevant to Moon and Mars exploration (e.g. geological analysis via seismic, magnetotellurics, field studies of rock analogues, as well as robotics and resource exploration/extraction in extreme environments), allowing participation across multiple research sectors. Australian expats, including scientists with leadership roles on key missions to the Moon and Mars, work for partner agencies. An Australian science program will leverage existing strengths to help partner agencies achieve their goals of robotic exploration, sample return, and a permanent human presence. Building on the success of our own exploration program, we will win preferred access to missions led by other agencies.

Background on Topic Area

Planetary science involves the study of planets, asteroids, comets and moons, and entire planetary systems. Its particular focus is the origin and evolution of objects in the Solar System. It is highly interdisciplinary, encompassing dozens of other fields. Planetary science is intimately linked to space exploration. Research priorities for overseas space agencies are defined around knowledge gaps in the field. Planetary science is thus central to most space agencies exploration and research efforts.

There is ~AU$15 billion of hardware currently at Mars, or ready to fly. The combined cost of two of those missions – Curiosity and Perseverance (Mars 2020) – equals the US cancer research budget. Two thirds of NASA missions are defined around planetary science knowledge gaps. NASA's planetary science budget in FY 2019 was AU$4.2 billion. Outside of human exploration and operations, planetary science is NASA's single biggest budget item, accounting for 13% of the total budget in 2019. NASA spends more on planetary science than it does on Earth science and observation, or on the Space Launch System. Other agencies – both small and large – also prioritise planetary science. This level of investment speaks to a deeper motivation than simply a desire to explore the solar system. It is just that: an investment. NASA, and other space agencies, fund planetary science and missions that pursue planetary research goals because they create direction and motivation for their domestic space industry. The science goals create a framework around which engineering solutions need to be developed, acting as a crucible for innovation.

Internationally, agencies view planetary science as the driver of their domestic space industries, not as an optional extra. **NASA and ESA have calculated that every $1 invested in science brings a $4-6 return**. Planetary scientists generate the science cases that define inspirational missions. They work with overseas agency collaborators to build transnational science and engineering teams on the highest profile projects. These projects attract and engage the brightest students. The result is a pipeline of highly qualified graduating scientists and engineers, with experience that goes beyond their own disciplines, having built relationships with colleagues at partner agencies around the world. Planetary scientists build the hardware that flies on missions: IP that has translated into space industry applications, and the broader economy. Planetary science drives innovation at home, and brings innovations from overseas agencies to Australia.

Australian industry cannot work directly with NASA, but Australian researchers can and do. Australian planetary scientists have relationships throughout NASA, ESA, and many other agencies, built over decades. Planetary science connects industry to those agencies.

The intimate connection between planetary science and a thriving space sector was recognised during the development of the Australian Space Agency. The Review of Australia's Space Industry Capability recommended that Australia should 'participate in discovery science missions as part of international consortia and national space competition missions'. In July 2018, then Minister for Jobs and

Innovation, Michaelia Cash, gave the keynote speech to the ASPI International Space Conference 'Building Australia's Strategy for Space.' As the Minister responsible for the new Australian Space Agency, she celebrated its imminent inauguration, outlined the strategic priorities that the agency would address, and identified Australian research strengths in five areas that the Agency would seek to build as a strategic priority. The Agency has moved forward on all but one of these. The outstanding element was the direction to build "…on Australia's research strengths in… planetary science".

Key Science Questions

The major goals of the Australian planetary science community align with international peers. Building on our existing research strengths, we see several key areas of investigation that Australian planetary scientists can progress or answer in the next decade:

1. *How did the Solar System form?*

What were the initial processes of solar system formation and the nature of the interstellar matter that was incorporated? We understand much of how the Earth works. How the Earth and other terrestrial planets, as well as how and where the gas giant planets formed, is still a mystery. What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and the evolution of their atmospheres, and what roles did bombardment by large projectiles play?

The Moon, Mars, and asteroids (from which meteorites come) as well as comets, contain a unique record of solar system formation. Australia is a world leader in the analysis and characterisation of extra-terrestrial materials, whether it be samples brought back by JAXA, NASA, and CNSA missions, or meteorites. Building on this key strength and analytical infrastructure in analysis of asteroid and comet samples, we see near-Earth objects as a logical target for Australian spacecraft to help answer the overarching question of how dust and gas came together to create our solar system, including at least one planet capable of supporting life.

2. *The formation and evolution of the Moon*

Following the flurry of activity during the Apollo era, the Moon has been comparatively underexplored. Mars has been the target of a co-ordinated research program for decades, visited by 15 NASA spacecraft. In contrast, NASA has returned to the Moon only 6 times since Apollo. There is so much that we still do not know about Earth's nearest neighbour. When did it form? What is its internal structure? What can its ancient surface, and record of impacts, tell us about the impact history of the solar system? Going back to the Apollo era, Australian planetary scientists have led the way in understanding the geological and impact history of the Moon. With the Artemis program we are entering a new era for lunar science, and Australia is well positioned to participate. The NASA Commercial Lunar Payload Services (CLPS) program offers an unprecedented opportunity, with low cost options to access the surface with lander or rover payloads, or via delivery of remote sensing platforms to orbit. Working closely with NASA on science projects as part of a mature Artemis program, Australian science teams can operate hardware on the surface or in orbit to address key knowledge gaps.

3. *Enabling human exploration: in situ resource utilisation*

Australia's track record in sample analysis means that we can be key partners with other agencies, characterising the composition of the Lunar and Martian surfaces, their material properties, and dust environments – all key to determining the economic and ISRU potential of the Moon and Mars, and constraining hazards to human health. This area is the focus of a co-ordinated NASA program – the Solar System Exploration Research Virtual Institute (SSERVI) – which supports domestic US science teams, and connects and co-ordinates their research with overseas partners. SSERVI was created to supplement and extend existing Lunar science programs, with a particular focus on connecting science with human exploration. Australia became a NASA SSERVI partner in 2015. US teams have a singular focus on volatile distribution, ISRU, regolith properties, and impact on human health. Australia has risen to become a key partner in SSERVI at the national level. Australian scientists are also members of three domestic US NASA SSERVI teams. Relationships built within NASA SSERVI on projects to determine volatile content and distribution for ISRU, our track record in sample analysis, and Federal support for Artemis, potentially make us a preferred national partner with NASA in this area.

4. *The Origin of Life in the Solar System*.

How, why and where did life evolve in the solar system? Leveraging key Australian strengths in astrobiology and analogue site studies (Western Australia has some of the oldest rocks on Earth), there is an opportunity to develop Australian payloads around key science questions and knowledge gaps. Key questions focus on the primordial sources of organic matter, whether Mars or Venus hosted ancient environments conducive to early life, and whether there are modern habitats elsewhere in the solar system with necessary conditions to sustain life.

Australian science payloads could target a 2026 launch window for Mars, and a likely NASA lander, as well as other international missions. Although Mars is well explored from orbit, surface science packages can address key knowledge gaps. This contribution could take the form of instrument payloads on a lander or a rover, or novel platforms such as drones, or micro-landers. Payloads could deliver analytical capabilities to measure trace gases, rock and soil composition and/or map groundwater distribution, feeding into identification of astrobiology targets and resources for future missions. Such payloads for small platforms will have diverse uses, with applications on the Earth, Mars, Venus, Moon and small solar system bodies. Australia can be a leader in this technological space because the minerals industry has driven development of deployable, remote operated analytical technology, along with airborne and ground-based geophysics and analytical techniques.

5. *The Evolution of planets: Pathways to habitability*

How have the chemical and physical processes that shaped the solar system operated, interacted, and evolved over time? The giant planets serve as laboratories to understand Earth, the solar system, and extrasolar planetary systems. Understanding the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres and climates will lead to a better understanding of climate change on Earth.

Mars today is dry, cold, and has little in the way of a magnetic field or atmosphere. In contrast, Venus is hot and shrouded in a thick greenhouse atmosphere. Observations of Mars' surface reveal features consistent with an active hydrosphere with rain, rivers and possibly a northern ocean early in the history of Mars. However, climate models have not yet been able to replicate such a warm and wet environment. Australian researchers are already working on this puzzle. We can provide the technological capability and theoretical know-how to conduct rapid, large-scale geochemical analysis of rocks, develop simulations of the surface climate and interior, determine the ages of various minerals, and characterize the isotopic variation of key elements. Importantly, understanding Mars will allow us to unravel other climate mysteries in the Solar System.

6. Summary

Given the current focus on the Moon, with low cost ride-along opportunities for orbiters and landers in the next 2 years, it is logical for our domestic program to begin with the Moon. Missions to near-Earth objects will follow. Building on this success, as a trusted partner with space validated hardware, we can anticipate ride-along opportunities to more challenging and costly targets, such as Mars. We also wish to engage with the priorities of our international partners, translating demonstrated success with Australian science investigations to preferred access to their upcoming missions: lunar sample return with CNSA, Mars sample return with NASA/ESA/CNSA, JAXAs mission to the Martian moons, NASAs Dragonfly mission to Titan, ESA's mission to the Jovian satellites, and NASAs Europa Clipper.

Recommendations

Achieving our vision does not require NASA or ESA levels of funding. Existing programs such as ASAs Moon-to-Mars (M2M) could get us far along the path, for a small fraction of the total program budget. Academics are used to highly competitive funding environments. Competition drives excellence. But achieving our 2030 vision does require a structured funding environment. And it does require ASA to engage with the research sector. As in other nations, now that we have a space agency, the viability of our research sector is necessarily tied to agency funding policy and strategy. We feel strongly that a modified ASA policy that enables Australian scientists to leverage the deep and broad relationships with overseas agencies, acting as intermediaries between those agencies and Australian industry, would help Australian industry and boost the domestic R&D sector. If ASA-funded projects are mission-oriented, with science and capability cases that engage agencies overseas, and that deliver real outcomes for Australian industry, then everyone benefits.

- RECOMMENDATION 1: Overlapping remits in a new funding ecosystem

Background: The Australian space sector has benefited from significant federal investment: to ASA, with the Strategic Infrastructure Fund, International Space Investment initiative, Moon-to-Mars program, and to the SmartSat CRC. But currently blue-sky planetary science and engineering is in danger of falling between the cracks in the new Australian space research funding ecosystem. SmartSat IP provision means that universities cannot leverage their relationships with overseas agencies to fly their hardware on those agencies' missions. In the case of ASA, it is currently unclear whether planetary science projects are eligible within current and future funding schemes.

Risk: Previously, although funding was highly competitive, spacecraft engineering or Moon/Mars projects would be funded by ARC. Now, perception of a funding overlap with SmartSat and ASA will mean that a hard-pressed ARC will step back. The low level of ARC funding that has allowed an Australian planetary research community to survive will dry up. This is an existential issue for the field.

Recommendation: ASA should liaise and communicate with other Australian funding bodies to develop a space and planetary science funding strategy, and clearly identify remits. Our suggestion is to follow the UK model. The UK Science and Technology Facilities Council (equivalent to the Australian Research Council) funds non-mission science. The UK Space Agency funds mission science and engineering. ARC would continue to fund non-mission science. ASA would fund mission science and engineering.

- RECOMMENDATION 2: ASA funding policy

Background: The future of the Australian research sector is tied to agency funding policy. Current ASA policy appears to be excluding science. Initially, the announcement of a $150M initiative to partner with NASA on exploration of the Moon and Mars appeared to be a real opportunity for Australian planetary science. But the draft document and consultation clarified that M2M does not include funding for science. Will ASA take a similar approach with future programs?

Risk: Forging enduring relationships with overseas agencies that are focussed on science and missions requires a domestic capability in these areas. Ongoing engagement with an entity like NASA Science Mission Directorate will necessarily require us to have projects with science cases, developed around missions. Overseas agencies can demonstrate a clear return on investment based around funding models that include science projects and missions. A "no science" funding model represents a unique experiment. In 10 years, with a model that does not involve funding for science, will ASA be able to demonstrate a similar return? At that point, with a substantially depleted research sector, there will be limited opportunity to pivot to a new policy, and our ability to engage with overseas agencies will be diminished.

Recommendation: ASA modify current and future programs to include university-led teams, allowing science cases that enable engagement with overseas agencies, while adhering to the ASA priority that there should be demonstrated benefits to industry. When considering missions, develop a program, rather than a delivery mechanism for a single project. Design all projects to be collaborative between industry and academia, with direct partner agency involvement. A package that includes science team involvement on missions for other agencies, and sample-return analysis, multiple Artemis-class cubesat missions ($8-10M per mission), payloads for CLPS landers ($1-2M per project), and a PhD program for collaborative projects that would allow internships for students at partner agencies, would have minimal overall impact on existing programs in terms of direct funding for supply chain and industry, but it would pump-prime the research sector, encourage engagement with industry, and set us on course for achieving our 2030 vision. The result could be full Australian involvement in missions with partner agencies, 4 Artemis-class cubesat missions, 6 payloads for CLPS landers, 1-2 tech packages on Mars rover missions, and 20 new graduate students in spacecraft engineering, with relationships across multiple overseas agencies. A single large mission is a high risk for a nation that is still building a capability. It benefits a small team, rather than a program that grows a research community and a sector. And the science benefit and inspirational value is not significantly increased over smaller missions. Multiple Artemis-class missions would spread the risk across more projects and teams, decrease cost and shorten the timeline for high visibility success, and minimise the project management overhead. Australia would get multiple inspirational projects, delivering regular high profile wins, and with multiple missions and projects, our relationships with overseas agencies would broaden and deepen across multiple areas and partners.

- RECOMMENDATION 3: Develop a modular approach to mission design

Background: There are 13 6U cubesats flying as secondary payloads on Artemis-1. Nine of these are science missions; 4 are technology demonstrators. Of the 9 science missions, 8 have buses developed by different, independent teams. This illustrates a standard approach in planetary mission design. Teams reinvent the same capabilities. R&D pathways are typically on a mission-by-mission basis.

Risk: Australia is a small nation. Our budget for R&D for missions will always be constrained. If we adopt a similar approach to other nations, with R&D focussed on a specific mission, rather than a program, our ability to deliver on our vision will be limited.

Recommendation: Australia should develop a space technology "toolkit", and a modular approach to mission design. We should identify key enabling technologies, and develop and validate them on multiple missions. The result would be that new missions can be developed rapidly from validated systems, built for interoperability. This does not require a restrictive top down approach to R&D. Competitive funding drives excellence. It simply requires that we identify key technology enablers, and have teams interact to ensure interoperability.