Space: capabilities and opportunities
Input to the mid-term review of the Astronomy Decadal Plan

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INTRODUCTION

With the establishment of the Australian Space Agency on 1 July 2018, the astronomy community in Australia is taking a renewed look at opportunities in space-based astronomy and at the prospects for our ground-based facilities to contribute to space activities. The Space Agency itself does not include astronomy or space science within its priority areas, but is building constructive relationships with international agencies such as ESA, NASA and JAXA that have significant astronomy programs. It has also identified the need for 'leapfrog technologies' and R&D development to enable the growth of the Australian space industry: these include areas where the Australian astronomy community has current or potential capability, such as optical communications and space situational awareness. In addition, the decreasing cost of access to space and miniaturization of instrumentation mean that contributing to, or even leading, space-based facilities is increasingly feasible within relatively small budgets.

CAPABILITIES

Capabilities within Australia relevant to space fall into two (overlapping) categories: firstly, research groups using space-based facilities; secondly, technical capabilities and facilities that are applicable to space missions.

Science capabilities include:

- Australian researchers are significant users of space-based astronomy missions, such as the Hubble Space Telescope and Kepler. At the time of the decadal plan, space telescopes accounted for 30% of optical/IR citation impact-weighted activity. Future space telescopes such as JWST will be critical for enabling Australian astronomy, complementing ground-based facilities such as the ELTs and SKA.
- Australia has a growing exoplanet research community. USQ has recently built MINERVA-Australis, a dedicated exoplanet observatory that will be used for follow-up observations from the Transiting Exoplanet Survey Satellite (TESS). The community is also exploring opportunities to buy into the UK-led Twinkle small satellite mission to conduct spectroscopy of exoplanets.
- The Solar System research community has strong ties with NASA through the Australian SSERVI node (NASA's Solar System Exploration Research Virtual Institute), which is led by Curtin University and includes 12 partner organisations. Team members have been part of science teams for spacecraft such as NASA's GRAIL lunar mission, JAXA's Hayabusa and NASA's Osiris-Rex asteroid missions, and Mars missions including InSight and Mars Science Laboratory.
- The Australian Desert Fireball Network, led by Curtin University, is a nation-wide all-sky science project that uses a distributed network of low-cost cameras to detect the impact of asteroidal and cometary material with Earth's atmosphere.

Technical capabilities:

- The Australian astronomy community has world-class strengths that can be applied to space-based facilities, including in radio receivers, interferometry, adaptive optics, infrared technologies and signal processing.
- Australia has a long history of providing ground-station facilities for space agencies, such as the Canberra Deep Space Communication Complex (for NASA's Deep Space Network) and the New Norcia Deep Space Ground Station for ESA.
- A number of Australian institutions are building capability in CubeSats, including UNSW, CSIRO and the University of Sydney. The University of Melbourne is leading the design of Skyhopper, a 12U CubeSat for near-infrared wavelength astronomy.
- Australia has demonstrated capability in the project management, system engineering and delivery of complex, large-scale astronomical instrumentation, which will position us well for delivering space-based instruments.
- Facilities such as the ANU Advanced Instrumentation and Technology Centre and UNSW's Concurrent Design Facility can contribute to the design, manufacture and test of instruments and small spacecraft.

OPPORTUNITIES

International missions

Although Australian scientists are significant users of space-based facilities, there has to date been little Australian partnership in these missions. Building on the relationships between the new Australian Space Agency and international agencies such as ESA and NASA provides a fresh opportunity for meaningful Australian engagement. This could take the form of science partnerships, or providing instruments for space telescopes or planetary missions.

Leveraging the current ground-station relationships with NASA and ESA could be one route to enable access to science missions. In particular, ESA is in discussion around the build of a new antenna at New Norcia: any Australian contribution to this cost would introduce the opportunity for science partnerships.

There are a number of mission opportunities that could be undertaken with international partners. These will need to be explored in more detail, but include contributing an Australian instrument to one of the forthcoming planetary missions or space telescopes. As an example, NASA's future solar system missions include the opportunity to deploy CubeSats alongside the main payload, which could address science goals of particular interest to Australian researchers. The cost of such an instrument would likely be in the range $5-10m, providing a cost-effective introduction to international engagement in space. Any instrumental contribution to an international facility could build on Australia's world-leading capabilities in optical and radio instrumentation, and in high data-rate signal processing.

Technology development and test

Australia's growing capability in CubeSats also provides an opportunity for developing and flight-testing astronomical instrumentation, and for building niche-capability instruments at low cost. CSIRO is exploring opportunities with partners for a series of Australian-built CubeSats that could be used for a variety of payloads in areas such as Earth Observation, communications, quantum technologies and astronomy.

Future space communications are likely to shift to lasers, including use of hybrid radio dishes with optically polished cores. Both NASA and ESA are experimenting in this area, and have plans to move both near-Earth and deep space communications to optical wavelengths. This area has been identified by the Australian Space Agency as a likely 'leap frog' technology for

Australia, where we could contribute world-leading capability, including from current astronomy groups such as at UWA and ANU.

Data and computing

Significant and unique science stems from the merging of radio, spectroscopic, and space-based datasets. With the radio data being largest and least mobile, the opportunity arises to lead data federation activities within the SKA Regional Centre, particularly with NASA/ESA datasets flowing through Australia, and making use of facilities such as the Pawsey Supercomputing Centre. In addition, transient astronomy is likely to be a key theme of the next decade. Transient detection often requires rapid processing of data, and opportunities arise for Australia to provide a rapid processing service for both NASA and ESA, at or near ground-station sites, to provide ultra-fast alerts.

Astronomy facilities for space applications

The majority of economic and research activity in space occurs within the near-Earth environment. Increasingly, facilities and techniques designed for the study of astrophysics are finding a role in this area, opening new opportunities for these facilities.

Space Situational Awareness (SSA) includes tracking active space assets and debris. SSA observations can be conducted by astronomical facilities, both optical and radio. Examples of current SSA capabilities from astronomy include the wide-field optical camera network FireOPAL, the passive radar capability of the MWA, and collaborations at Mt Stromlo with EOS Space Systems. Other current facilities of relevance are ASKAP, Parkes, and the ATCA at radio wavelengths. The future SKA in Australia will be a superb machine for SSA.

The monitoring of active and debris objects in orbit is considered a critical activity for collision risk mitigation (and response) and for verifying events in what is becoming a heavily contested military arena. Astronomical facilities can undertake SSA for research, economic benefit and wider societal impact.

The Earth's ionosphere is the closest part of the near-Earth environment and important for radio frequency communications on Earth. The MWA has been used to study and monitor the ionosphere in great detail, as a by-product of astronomical observations. The future low frequency component of the SKA, to be built in Australia, will have a similar capability. In addition, radio telescopes such as the MWA are capable of detecting and tracking coronal mass ejections from the Sun. Such events can cause massive damage to satellites in orbit, electricity grids, oil and gas pipelines, and communications networks.

Inspiration and education

Space and astronomy are uniquely inspirational in encouraging students into STEM s and enabling wider societal support for science. Recent interest in events such Cassini's descent into Saturn and the New Horizons flyby of Pluto have demonstrated the pull of space on the public's imagination: this will be further highlighted by next year's 50th anniversary of the moon landing. There is an important opportunity for the astronomy and space communities to work together on STEM activities, building future capability in both fields.

Space Science Decadal Plan

A number of the opportunities and capabilities explored here are also relevant to the Space Science decadal plan, which covers everything from Earth's middle atmosphere (from about 40 km above Earth's surface) to the centre of the Sun and the boundaries of the solar system including the planets, and relevant space technology. The space science community is currently starting work on their next decadal plan, which may provide an opportunity to align recommendations and messages across astronomy and space science.