Australia in Space: a strategic plan for Australian space science

Working Group Topic: Space Technology

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Vision statement

It's 2030 and Australian space science comprises a consistent flow of space science missions that vary in field, size and complexity. The nation has the technology, knowledge and infrastructure to plan, design, build, launch and execute these space science missions that directly positively impact the lives of Australians.

Background

Space technology developments typically arise in response to science mission drivers. The science working groups informing this report have highlighted a number of potential missions and capability developments required for positive and aspirational science outcomes. This section summarizes the technologies that map to these science drivers in order to identify opportunities for collaboration and investment.

Two key themes have been identified as primary space technology developments to enable these mission over the upcoming decade. First, strategic technology developments are required to enable a sustainable sovereign space sector and meet the requirements of the space science community. Currently in Australia these technologies may be lagging international players, however are recognized as prerequisites for a functional space ecosystem that can support Australian science, commercial and Defence space missions. Gaps exist within the Australian sector throughout the space mission lifecycle and identifying and filling these gaps is essential to be able to respond to science mission requirements.

Second, it is necessary to identify advanced technologies where Australia could play a key role in the international space sector, by examining space technology trends that align with Australian industry strengths. The drive toward low-cost satellites and space products and increasing requirements for flexibility and adaptability within the developing 'Space 2.0' industry will also present opportunities to compete internationally where emerging trends have yet to be fully capitalized on.

Science Drivers

Earth Observation

Recent trends in EO data processing have looked to 'democratize' the downstream value-added chain by increasing accessibility and usability of EO data. For example, data from the LandSat and Copernicus missions can be processed through cloud based services. Australia has historical strength in data processing of such EO data and has previously excelled in breaking down these data for agriculture and other end users into an analysis-ready state using technologies such as the Open Data Cube.

Further democratization of this data chain will be available in the future, and a new market is becoming available targeting smaller and less sophisticated end-users that can benefit from satellite data. For Australia to lead in this sciences service field, specific processing algorithms and methods are required that can break information down into smaller and more dedicated chunks. The current data sets are in the petabytes and are growing constantly. Processing of this large volume of data may suit machine language sorting and processing algorithms.

On the upstream end, Earth observation payloads are advancing, however the trends for sovereign Australian satellites will be toward specific niche missions and payloads that suit the Australian community need or provide a unique capability to international partners. The proposed AquaWatch mission requires development of targeted SWIR/Optical imagers on a satellite constellation providing fast temporal resolution. Additionally, more complex on-board processing for data reduction is likely to become mandatory to ensure efficient use of the link budget and to support the calibration and validation of the satellite sensors.

Planetary Science

Planetary science missions in Australia are in their infancy, and the community have identified a desire to produce dedicated and niche nano- and small- satellite missions. This aims to demonstrate sovereign capability to enable and unlock potential collaboration with international partners. Significant international development over the next 10 years is expected in high value nano- and small satellites, and this can align with an Australia ambition to provide planetary science missions with this stepwise development approach. Launches for planetary science missions are highly likely to be provided by international partners in the near to medium future.

Heliospheric Science

Heliosphere science specifically requires development in, but also importantly access to, high-performance computational resources.

SSA & Space Weather

Current on-ground specific sensor technologies being developed in Australia covering adaptive optics, bi-static radar and lidar technologies, however the vast majority of SSA sensor technology is operating in a research mode rather than a dedicated operational mode. This results in a divide between the sensor data and the groups that produce the algorithms for orbit and trajectory predictions. The next steps for SSA focus on producing an integrated collaborative SSA system to support both commercial and military applications. Efficient utilization of cloud computing with a standardized "data lake" could provide a clean link between sensor data and algorithm developers that is currently missing. A strong SSA ecosystem would then naturally support sensor technology development over the next decade.

The SSA & Space Weather working group identified a specific dedicated in-space SSA and Space Weather mission to map the thermosphere and ionosphere from space using a constellation of small satellites. There are many options for sensor and payload technology for such a mission that already exist at a relatively high TRL. Developing the technology in Australia for such a mission is an achievable goal in the 5-10 year timeline and would place Australia in a better position to look at larger Space Weather missions.

Communications

Several specific technologies have been highlighted by the communications working group as key development opportunities for the next decade, including case studies in the areas of high frequency microelectronics, in-space optical communications, and reflect-array antennas and metasurfaces. These technologies are near the forefront of space communications and there is capability here in Australia to leverage. Providing these technologies to upcoming missions within Australia would provide opportunities to demonstrate and iterate. However, development of these technologies to the level required to impact the global space ecosystem over the next 10 years would greatly benefit from international collaboration. In particular, Australia has a natural geographic advantage in optical communications and this provides a pull for collaboration with international partners.

Cross-Cutting Technologies

Some specific technologies have been highlighted above. This section identifies technologies that cut across multiple sectors and complement the various space science drivers, and also identifies the step-change technologies that will position Australian space science into the future. Three key segments are highlighted.

On Ground Processing

Significant cross-over exists in the on-ground processing domain. Over the next decade both the SSA and EO areas require developments in efficient cloud computing to provide an integrated and robust link between the data gathering and pre-processing community and the end-user. The focus for both communities is to combine inputs from a wide range of sensors and make the large volume of data highly accessible. This will allow researchers and commercial industry to interrogate data with exploratory data analysis and machine learning algorithms.

Payload On-Board Processing

Many of the science satellite missions and opportunities examined require a step-change in payload on-board processing for small and nano-satellite missions. Large volumes of EO data can be produced very quickly, however it is the efficient use of the data chain that can provide Australia with a competitive advantage. Similarly, planetary science missions are severely constrained by the link budget, requiring much smarter solutions to data collection. This is especially pertinent when an international partner is required for the ground segment.

Simple on-board processing such as feature detection can provide a rapid pass/fail criterion for data downlink, and further ahead developments in on-board processing for complex image cleaning, processing and calibration could significantly increase the efficiency of the satellite link budget. Additionally, utilizing intelligent imaging systems with sensors for anomaly detection and machine learning techniques such as feature extraction to pre-process and select data for downlink could significantly increase the satellite value and utilization.

This is an opportunity for Australia, and significant effort should be made to ensure that payload on-board processing hardware and software for all sovereign satellites is developed in Australia. Collaborative research in this way may lead to innovative solutions.

Access to Space

Access to space includes launch vehicles and complexes, however, also encompasses spacecraft technology and mission design techniques to reduce the complexity of executing space missions as well as increasing the confidence in them. The space missions highlighted in this report can be broken into two styles: constellation missions that require low cost and fast response; and high-value nano- and small satellite missions using dedicated niche science satellites and payloads that ultimately act as a stepping stone toward larger sovereign or internationally collaborative science missions.

Constellation nanosatellites

A cost effective and responsive Australian development, launch and operations capability would greatly benefit the constellation missions examined here. This pressure on the whole mission chain, from concept design through to manufacture, test, launch and LEOP. A number of key drivers and opportunities are highlighted here.

- A well maintained and utilized concurrent design facility (CDF) can provide an efficient way to transition from an initial concept through to preliminary and detailed design. Additionally, digitization capability via such facilities can enable delta-developments using similar missions or product families for swifter early phase mission design and synergistic architectures.

- A highly responsive launch capability to send small and nano-satellites to LEO is required to provide fast response and constellation missions. This capability will ideally be available in Australia within a decade. The launch vehicle providers will develop technologies specifically to cater for this market, potentially primarily driven by the commercial and defense sectors. This knock-on opportunity for small science experiments to rapidly design, launch and iterate greatly increases the capability to push boundaries, since it creates the opportunity for spacecraft technology to rapidly transition from TRL5 to TRL9 with a prototype and iterate approach rather than a stepwise TRL approach.
- Ultimately, successfully developing and executing space science constellation missions will enable a Sovereign satellite prime(s) manufacturing capability for multiple satellite missions. This will encourage commercial IoT and defense operators to consider such missions in Australia
- Satellite operations and in particular LEOP need to be efficient and resource light. For short life satellites launched in batches there is a time critical aspect to commissioning each satellite and autonomous LEOP phases will be required, with advanced on-board processing required to accommodate this. Operational constellations will require far superior autonomous operations than currently exist and there is potential to exploit the Australian Space Agency Mission Control to ensure synergies are seen between science missions and their commissioning phases.

High value nanosatellites and small satellites

For satellites with significant payload development cost as well as satellites beyond low Earth orbit there is significantly more focus on reliability. There are still many advantages to using standardized nano- and small- satellite platforms for such a mission, but a different approach is required for the satellite design and verification phase. Development costs for dedicated sensors for Earth observation satellites could preclude the use of cheap, very low lifetime satellites, and launch opportunities for the planetary science community are infrequent and expensive compared to nanosatellite low Earth orbit missions.

The step toward such high value missions requires reliable processes to be able to produce a dedicated planetary class nanosatellite bus for high value and deep space missions and eventually a small satellite bus for satellites of around 100 kg for Australian missions in LEO. Both of these can be achieved within a 10-year timescale given sufficient investment.

Communications technologies for such missions have been highlighted above, while radiation tolerant electronics will become mandatory for these missions with significant research required in this field in Australia. Additionally, having a default scalable Australian propulsion module for Australian missions would potentially reduce flexibility in mission design but would greatly increase the variety of missions that are currently possible. The SSA working group also identified propulsion systems as a requirement for controlled de-orbit for small satellites. Guidance, navigation and control systems, and thermal control systems, require developments that will likely be mandatory in future missions.

Recommendations:

There is genuine reason to believe that Australian space technology can answer the headline vision statement of this report. This can only happen by ensuring that science, defense and commercial missions draw on the collective Australian space community to deliver them. Space missions are requirements led, and both Australian industry and research institutions can demonstrate the capability and flexibility to plan, design, build, launch and execute these space missions.

Recommendation 1.

Develop a true sovereign capability to design, launch and operate small satellite missions and constellation nanosatellites and microsatellites. Breaking this access to space barrier opens multiple opportunities for space science and technology**.**

A set of cornerstone Australian science missions with drivers to ensure development occurs in Australia is potentially the most feasible way for Australian industry to achieve this.

Recommendation 2.

The following advanced technologies present an opportunity for Australia to compete at the cutting edge of space technologies, adding value to the global industry.

- Optical communications, leveraging Australia’s geographical advantage
- The development of data processing facilities that aim to connect the data gathering and pre-processing community with the end-user while leveraging Australia’s historical strengths in EO data processing
- Smart and adaptive on-board processing for small satellites and the associated technologies required. The target is to break ground in the still emerging fields of constellation and high value nanosatellites