2022 ASTRA WHITE PAPER - ACACIA

THE GREEN CASE FOR EARTH OBSERVATION

Growing sovereign capability for Australia's future.

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Introduction

Australia's environment is vulnerable to changes due to weather, natural disasters and fast paced urbanisation. Earth observation (EO) is key to managing and responding to these changes.[1] It is essential that Australia improves its industry capabilities and encourages relationships between stakeholders to develop sovereign EO capacity.

Due to the capital investment required, satellite infrastructure has historically not been prioritised.[2] Even as investment picks up, the country is still a long way from independent capability.[3] Australia also faces bottlenecks, such as a lack of industry knowledge and personnel who can turn satellite data into usable information.[4] This white paper establishes the need for end-to-end coordination of the Australian space industry, from satellite launch to ground application. This will ensure Australia has accessible and sustainable sovereign EO data access for its air, land and water.

Methodology and Assumptions

This white paper contains seven recommendations developed by Team Acacia during the three-month Astra Program. Our team reviewed existing Australian EO resources, including satellite facilities, data processing solutions, education and end-user engagement. To assist this process, we adopted personas of key stakeholders in the Australian space industry, including SmartSat CRC ('SmartSat') and the Department of Agriculture, Water and the Environment. We also engaged in discussions to identify common stakeholder interests. These occurred during seminars featuring experts from SmartSat, CSIRO, Inovor Technologies, Microsoft Azure and Swinburne University.

This whitepaper is written under the assumption that a significant amount of funding will be invested in growing the Australian space industry in years to come.

Topic 1: Satellite Sovereignty in Australia

Australia's vulnerability to severe weather events and natural disasters makes the country reliant on real time EO data to predict and monitor affecting events.[5] The threat of a denial-of-service (DoS) is increasing as Australia continues to depend on foreign satellites. A DoS could be catastrophic for the population and economy, as our ability to monitor environmental changes, resources and agricultural areas, would be adversely impacted. Meteorological monitoring, weather forecasting, warning systems and ocean observation would be the most affected, as the Bureau of Meteorology almost solely relies on EO data.[6]

Recommendation 1: The Australian Government, Through the Australian Space Agency and alongside SmartSat, Should Increase Investment in Sovereign Infrastructure

Australia has recently taken its first steps towards satellite sovereignty, committing to launch the Australian Defence Satellite System for military communication purposes.[7] However, equivalent resources have not been allocated towards Australian owned EO satellites.[7]

The Australian Government should invest in Equatorial Launch, Northern Territory's (NT) Arnhem Space Centre (ASC), which will be equipped with three launch pads to accommodate sub-orbital and small satellite launches.[8] Additional funding would facilitate infrastructure to accommodate larger-scale orbital missions. As an equatorial location, launch payload to fuel ratios are improved, increasing cost-effectiveness and reducing carbon dioxide emissions.[9]

Satellites launched from the ASC can give coverage of over two dozen nations, as well as the Indian and Pacific Oceans. This data will enable Australia to assist neighbouring countries in extreme weather events and coordinate more effective disaster responses.[10] Investment will also future proof the ASC in anticipation of increased demand for sites able to launch larger satellites.[11] This will position Australia as a regional leader in an area of significant geopolitical importance and secure our country's alliances with strategically important neighbours.[12]

Alongside government investment in the ASC, industry must also contribute to expanding sovereign infrastructure. In conjunction with the NT Government and First Nations people in Arnhem Land, SmartSat and its partners should develop a proximate space manufacturing hub similar to the South Australian Space Park.[13]

SmartSat has strong relationships with researchers, manufacturers and end users, placing them as the ideal conduit to help fill and grow this park. This could assist in the establishment of ride-share agreements and combining EO datasets, as well as reduce financial barriers for start-ups - all the while stimulating the Australian space economy, increasing Australian company's international competitiveness and creating more jobs in the sector.[14]

Recommendation 2: The Australian Space Agency Should Develop Sovereign EO Satellites

The Australian Space Agency should increase funding for private companies, such as Exci,[15] to maximise the use of pre-existing EO technologies. In the future, this funding should shift to the creation and launch of sovereign satellite technologies. Specifically, investment should be focused on satellite technologies which will be capable of meeting the diversity of needs arising from Australia's size and variable environments. Some examples of potentially ideal technologies are:

1. Synthetic Aperture Radar (SAR) Satellite Imagery which could significantly improve how we track natural disasters and identify areas at high risk.
    - It is ideal for mapping topography, movements of the ground surface, land use change and damage to infrastructure.
    - It is capable of gathering data in all weather conditions.[16]
2. Multispectral EO Satellites, which can be partnered with smoke detection stations, drones, and firefighting or spotting aircraft to improve response times during Australia's bushfire seasons.
    - They are capable of collecting visible and infrared images. Data processing mechanisms would need to be improved in line with recommendation 3 to obtain maximum benefit.
    - EO data of this type is capable of detecting fires within ten minutes of ignition.
    - They require a geostationary satellite or twenty-four nanosats in low earth orbit.[17]

A long-term government investment plan will allow Australia to grow sovereign EO capabilities, without losing access to data in the short term in the event of a DoS.

Topic 2: Processing Data from EO Satellites

EO satellites gather a tremendous amount of data at great speed and transmission rates exceed hundreds of terabytes per day.[18] Supercomputers are required to process this quantity of data, but they are increasingly time-, cost-, and resource-intensive.[19] EXA1 alone uses nearly five MegaWatts.[20] More supercomputers are needed if the industry continues its current trajectory.

Extracting useful information in real time remains a major challenge. Creating a more efficient means of processing data should be a priority if we are to continue to use satellites. Artificial intelligence (AI) tools, particularly in machine learning (ML), offer a solution, as ML models can sort data at a faster rate and lower cost than human experts.[21] ML utilisation in EO is still in its infancy and further adaptation to geoscientific analysis is required to improve its usability.

By improving Geospatial Artificial Intelligence (GeoAI) models, supercomputers will be more efficient in processing information, reducing the power, and thus environmental cost, needed for EO.

Recommendation 3: EO Researchers Should Develop ML Models that Incorporate Physical Laws and Uncertainty Propagation to Improve Credibility and Predictive Capabilities

Hyperspectral satellite images extend beyond the visible range and contain different properties to natural images.[22] EO data also covers a wide range of spatiotemporal scales and types. These dimensionalities raise significant computational challenges, leading to limitations in developing optimum ML models.

The amount of training data required to create an acceptably accurate model is very large. High quality models that are known to perform well in these training datasets deviate in analysing data outside of their spatial and temporal domain. Labelling of EO datasets is also conceptually difficult and requires trained personnel.[23] Avenues to educate EO experts is elaborated on in Recommendation 5.

EO researchers from universities and government departments should develop models that are not only accurate, but also credible, by incorporating the physical laws (such as laws of conservation of energy, mass and momentum) governing the Earth system into ML models, increasing confidence in predictions.[24] Hybrid physics-aware ML models have shown improved modelling in terms of consistency and interpretability.[25] Statistical methods should be integrated into models to allow for the propagation of uncertainties.[26]

The Earth system is stochastic,[27] and therefore, scientists must incorporate this characteristic and develop uncertainty-aware models. Additionally, quantifying uncertainty can give experts confidence scores to help them decide which models to use and whether to reuse results.[28]

The results produced by ML models should be, at minimum, consistent with the patterns observed in physical models.[29] Performance and accuracy of the ML models should be tested against data derived from current physical and numerical models of the Earth. This is important where there are limited training data sets. It also helps to assess extrapolation issues.

Recommendation 4: The Australian Space Agency Should Develop an Australian Global Catalogue Platform to Increase Data Accessibility

Increasing EO data accessibility leads to greater amounts of research that can be performed with the images acquired from space. Research can be used to inform environmental policy makers and predict the Earth's response to climate change. To provide accessibility, data produced by Australian satellites should be shared in an Australian Space Agency owned global catalogue, similar to the United States Government Open Data Portal.[30]

Industry members like SmartSat are ideal conduits to encourage sharing of information in this manner due to their existing partnerships with EO research organisations. Private companies and businesses can utilise this global catalogue to provide services to customers interested in the EO sector. The benefits of using EO data in ground applications is discussed further in Recommendation 6.

To support usability, the infrastructure and framework for sharing data between researchers and private companies needs to be improved. An internally accepted framework, such as the FAIR (findable, accessible, interoperable, reusable) data management principles, should be applied to ensure best practices for the documentation, storage and sharing of datasets and ML models.[31] These principles improve the ability of machines to automatically find and use data and enhance its reusability.

Topic 3: EO data education and skills outreach

A bottleneck exists in the application of EO data for Australia's end users.[32] SmartSat's 'Skills Gap Report' found that the Australian workforce and educational sector possess most of the skill sets required by the Australian Space Skills Taxonomy, however, there remains shortages in some areas of expertise necessary for a thriving space industry.[33]

Currently there is no national framework for space science education. Australia is the only member of the International Space Education Board not represented by a national space agency. Instead, it is represented by the state-based Victorian Space Science Education Centre (VSSEC) which incorporates STEM into school curriculums.

Recommendation 5: SmartSat Should Collaborate with the Australian Space Agency to Develop a Primary to Tertiary Education Framework

In order to harness the full potential of EO data in the future, it is important to encourage student engagement with EO technology, data and its applications.[34] The Australian Space Agency does not have an educational mandate, however, as a part of the Australian Government, it is best placed to develop a national education roadmap to ensure Australia's future EO capability.[35]

The Australian Space Agency should collaborate with industry and the Department of Education, Skills and Employment to develop primary and tertiary EO education frameworks. This would allow industry input into developing Australia's next generation of experts. SmartSat should take a leading consultative role in this process based on its prior work in educational outreach.[36]

Student engagement with EO application and innovation is difficult by the time they are able to understand such topics at a tertiary level.[37] New frameworks should expand on initiatives such as the Swinburne Youth Space Innovation Challenge. These programs encourage high school

students to be engaged with space science concepts and reinforce the viability of space as a desirable career path by linking students, tertiary students and industry professionals.[38]

The frameworks should include diversification of tertiary opportunities. For example, introducing EO data analysis into an urban planning subject could lead to greener city design and better disaster management. This would require coordination with certifying bodies of other disciplines to ensure that they are able to be incorporated. The success of projects such as Minderoo Foundation's 'Fire & Flood Resilience' highlight the importance of connecting EO to real-life applications, in a format that is accessible and understandable.[39]

There is also an issue of talent retention in Australia. A national skills framework through SmartSat should look to expand funding for space-related postgraduate courses and continue to link students with industry to produce research that can be translated into tangible outcomes.

SmartSat currently sponsors PhD students,[40] but this intervention is not early enough. Without increasing educational opportunities earlier, such as through a masters sponsorship program, Australia will continue to lose postgraduate students to Europe, where more opportunities exist in the space sector and the cost of a degree is lower.[41] Due to the growth of the space industry, employers are looking for more experienced and skilled workers.[42]

There is value in retaining Australian tertiary students, as they have a familiarity with the local environment and will be better placed to apply EO concepts to the Australian environment. This will bring major benefits for the industry by increasing the local talent pool, potentially introducing more educators and start-ups to an industry which aims to be worth $12 Billion by 2030.[43]

Topic 4: Cross-Industry Collaborations

As EO technologies develop, the opportunities for collaboration between Australian space and non-space sectors grow. As seen with fisheries, farmers, and land and marine management authorities, which are key for a 'green transition'.[44] The following recommendations propose a plan to grow dialogue channels between EO and terrestrial industries, to minimise overlapping technologies and resources, and encourage innovation of environmentally sound solutions.

Recommendation 6: SmartSat, and Industry More Broadly, Should Integrate Earth and Field Observation Infrastructure to Improve the Commerciality and Integration of EO Data Into Existing Markets

SmartSat and private industry should facilitate integration between existing infrastructure for field data, and EO data. This will create long-term beneficiary relations that guarantee the success of future projects, via an interconnected network of data support and connections.

This integration has been achieved by the Global Ocean Observing System (GOOS). The GOOS hosts tethered and drifting buoys and sensors whose data samples, in conjunction with satellite data, help identify key aquatic stress zones and provide practical information to marine protection organisations and more.

Amalgamating the information sources generates a network of complementary data,[45] serving two central purposes:

1. Reducing the expenditure of research and observation organisations on ground surveillance maintenance where EO fills the gaps instead; and
2. Raising awareness of integration opportunities and opening doors to increase collaboration with non-space industry personnel and organisations.

Despite boasting detailed insight, collecting field data can be resource and time intensive.[46] However, proven potential to integrate field data from ground monitoring stations with EO data provides a broader insight into subject matter, potentially mitigating incomplete data sets by confirming uncertainties.

GEOGLAM, a global agriculture monitoring initiative, employs a range of Sentinel, Landsat and Modis missions using data from EO and ground technology to provide meteorological and soil insight for research. Ground technological applications include recording soil temperature, emissivity, flora density, and carbon content observed from orbit, however factors such as thick foliage may obscure minute details.[47] Thus, further insights can be gleaned from incorporating terrestrial observation, such as crop yield and water bodies.

By using pre-existing ground and satellite infrastructure, Australia can construct shared data streams of precise information and boost partnerships and commercial viability.

Recommendation 7: SmartSat Should Increase Marine Industry Collaboration to Improve Australian Marine Monitoring Capabilities

Oceans cover approximately 70% of the Earth's surface, absorbing over 90% of the planet's heat and over 25% of our emitted carbon.[48] Oceanic carbon and nitrate cycles regulate atmospheric CO^2 levels and lessen the impact of climate change.[49] They are a major source of food and resources for Australia, worth AUD$80 billion in 2021, excluding their tourism and quality of life values.[50]

Since marine ecosystems are highly vulnerable to environmental changes, SmartSat should collaborate with Australian marine management and aquaculture industries to apply EO data to create environmentally sustainable solutions.

The Australian Space Agency highlighted that increasing funding in EO for marine monitoring purposes was a priority for Australian EO capabilities between 2021 and 2030.[51] By opening dialogue channels, applications of EO data to maintain healthy marine ecosystems will grow.

A model initiative to consider is the Maritime Connection Days hosted by Business France between 2020 and 2021.[52] This would enable the space industry to connect with potential collaborators and end users, highlighting the commercial opportunities and inviting other industries to work and invest in EO.

SmartSat's high-level cross-industry engagement would complement similar events. The Australian Government with the Asia-Pacific Economic Cooperation have identified key opportunities for increasing marine observation using EO capabilities. These encompass logistics, oil and gas prospecting, disaster management, ecosystem degradation, pollution monitoring and precision aquaculture purposes.[53] These opportunities will not be realised without increased cross-industry dialogue.

Recommendations

Topic 1: Satellite Sovereignty in Australia

Recommendation 1: The Australian Government, Through the Australian Space Agency and alongside SmartSat, Should Increase Investment in Sovereign Infrastructure.

Recommendation 2: The Australian Space Agency Should Develop Sovereign EO Satellites.

Topic 2: Processing Data from EO Satellites

Recommendation 3: EO Researchers Should Develop ML Models that Incorporate Physical Laws and Uncertainty Propagation to Improve Credibility and Predictive Capabilities.

Recommendation 4: The Australian Space Agency Should Develop an Australian Global Catalogue Platform to Increase Data Accessibility.

Topic 3: EO data education and skills outreach

Recommendation 5: SmartSat Should Collaborate with the Australian Space Agency to Develop a Primary to Tertiary Education Framework.

Topic 4: Cross-Industry Collaborations

Recommendation 6: SmartSat and Industry More Broadly Should Integrate Earth and Field Observation Infrastructure to Improve the Commerciality and Integration of EO Data Into Existing Markets.

Recommendation 7: SmartSat Should Increase Marine Industry Collaboration to Improve Australian Marine Monitoring Capabilities.

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