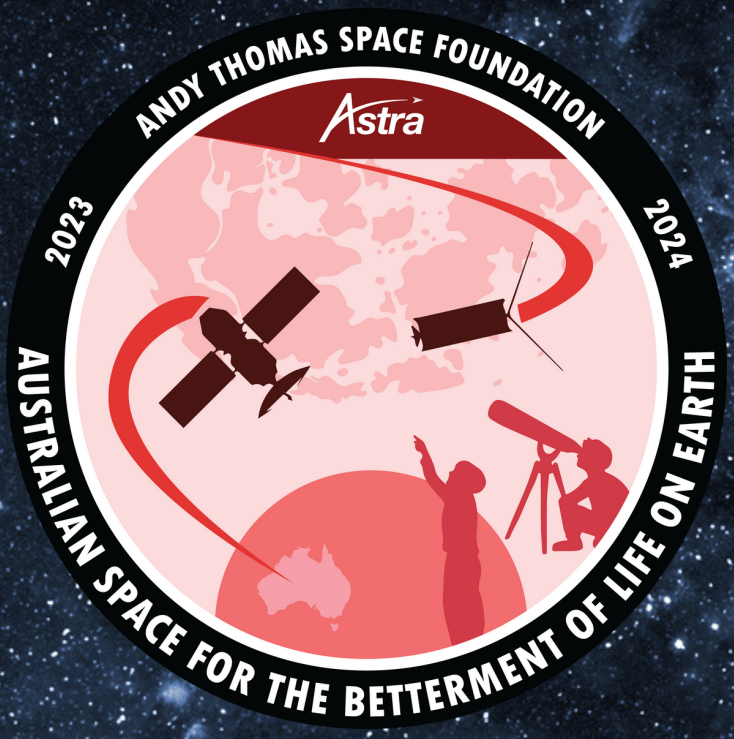

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Space for Earth

Beyond Boundaries: Advancing Life on Earth Through Space

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Introduction

Space technologies have historically been driven by a quest for discovery and understanding of the cosmos. The consequence of space exploration extends far beyond understanding; pivotal technological advancements can enhance the quality of life on Earth[1]. *'Beyond Boundaries'* presents a comprehensive analysis of how a variety of strategic recommendations can bolster Australia's capabilities throughout the space industry, while also recommending key space technologies that can be repurposed to benefit terrestrial life.

Beyond Boundaries is divided into two broad sections, each with several recommendations within it. Section one is entitled *Empowering Australia's Space Sector - A Blueprint for Strategic Advancements.* These recommendations focus on driving systemic changes within the Australian space sector to foster innovation and economic growth, the expansion of educational initiatives and the collaboration between government and industry. Section two is titled *Harnessing Australia's Space Sector - Utilising Space Technologies for Earth's Challenges. It* includes recommendations that aim to utilise Australia's space capabilities to address Earth-based challenges, empowering industries and sovereign capability, improving knowledge of human physiology, enhancing environmental and agriculture monitoring through predictive analysis and contributing to mitigating global challenges such as climate change.

Problem Statement

Australia has an inherent advantage in regards to developments in the space industry due to its geographical location, strong international partnerships and unique technological strengths, however, this is not being fully utilised. This report aims to address how Australia can capitalise on its strengths in the global space sector and advance space development to improve the quality of life of those on Earth.

Methodology

During the 12-week period of the Astra Program, Team Banksia developed nine recommendations to be presented to the Australian space industry. Through diligent research, discussions and guidance from professionals in the industry, Team Banksia developed key recommendations with the common goal of bettering life in Australia through the space sector.

Team Banksia approached the development of its recommendations as prospective stakeholders in the space sector, to effectively understand its limitations and areas where improvements could be welcomed. Through independent and group research, coupled with extensive discussion, Team Banksia was able to refine its knowledge to generate the nine recommendations believed to be most pertinent to the Australian space industry.

Some critical assumptions were made to ensure the accuracy, cohesion and success of this white paper. The topic thesis was broadly interpreted to enable recommendations directed both towards the Australian Government and Australian Space Agency ('the Agency') and to industry, including the Andy Thomas Space Foundation ('the Foundation').

Section 1: Empowering Australia's Space Sector - A Blueprint for Strategic Advancements

Recommendation 1: The Andy Thomas Space Foundation should expand and develop its *Kids in Space Program* to focus on the senior secondary school level.

The Andy Thomas Space Foundation should expand and develop its *Kids in Space Program (KISP)*, which aims to inspire primary school aged kids to identify and solve real-world problems relating to space,[2] to focus on senior secondary students and educators. This expanded program would aim to further promote the space awareness *KISP* implements, while adding a distinct focus on prospective careers in the Australian space sector. Although the Foundation currently boasts initiatives for secondary students, it does not have any generalised programs directed at secondary students[3]. This program would bridge the gap between the more rudimentary *KISP* and the *Mars Program,* a project-based program for years 7 through 10 students.

This recommendation advances the Foundation's vision, mission and purpose.[4] The existing landscape of similar programs do not directly target the senior high school demographic;[5,6,7] a demographic which is most critically engaged to expand the Australian space sector and sovereign space technology in the near future. Current tertiary projects such as the Australian Universities Rocket Competition, Australian Rover Challenge, alongside numerous CubeSat initiatives such as the University of Melbourne's SpIRIT, already provide extracurricular

opportunities for students attending university. Therefore, the Foundation's successful application of this program would ensure that students of all ages can engage with the space sector.

This recommendation is specifically directed toward senior secondary students, however, its scope may be expanded to be more influential. Rather than just being an extracurricular, opt-in program for students, the Foundation may propose integrating a focused space topic in the Stage 5 curriculum combining elements from distinct hard sciences taught at this level. Further, developing the existing *Mars Program* for years 7 through 10 students into a smooth pathway in this new program would allow students to engage with the Foundation's initiatives every year.

This recommendation is intended to be implementable with minimal upfront costs. The scope of the program would be dependent on investment from the Foundation, possible industry or local business sponsors, and if students pay to attend. As such, the limitations of this recommendation are in the financial investment provided and possible student numbers in the program itself. Ideally, maximising the reach of this program would forward the Australian space sector's interests by fostering passion of students and encouraging space career pathways.

Recommendation 2: The Australian Space Agency, with collaboration from the Andy Thomas Space Foundation, should develop a structured collaboration framework between government and private space industry for effective joint space initiatives.

Collaboration serves as the cornerstone of innovation and advancement in the space sector.[8] A structured collaboration framework between the Agency and the private space industry is essential to drive joint space initiatives. Australia is presently ranked 18th among G20 nations in terms of space investment.[9] Worldwide, governments are the main investors in space activities.[10] However, there is a discernible shift occurring in public-private relations within the space sector,[11] driven by a growing acknowledgment of the significant economic benefits derived from collaborative space endeavours.[12] Australia can leverage this and further enhance its collaborative efforts by drawing inspiration from successful international models. For instance, initiatives like the Collaborations for Commercial Space Capabilities-2 (CCSC-2)[13] in the United States provide valuable insights into effective partnership strategies.

The CCSC-2 programme, led by NASA, exemplifies effective collaboration between government and private entities, resulting in notable advancements in space-related technologies[14]. Through unfunded agreements, CCSC-2 facilitates collaboration by leveraging NASA's technical expertise, experience, technologies, and data to advance commercial space-related efforts, demonstrating the transformative impact of collaborative efforts between government and private entities with many innovations originally developed for space missions finding practical

applications on Earth.[15] This success emphasises the significance of strategic collaboration between government and private sectors in driving advancements in the space sector.

Building on the lessons learned from initiatives like CCSC-2, Australia could leverage similar partnership strategies to accelerate its space capabilities and foster innovation. This approach could help Australia overcome its lag in space investment relative to other OECD countries. The key initiatives listed below leverage the strengths of both government and private entities, accelerating technological innovation in the space sector and driving economic growth.

- Improve pathways for small and medium-sized enterprises (SMEs) to participate in government contracts related to space by simplifying grant application procedures.
- Create joint research and development programs with shared funding and resources from both government and private entities.
- Facilitate technology transfer and intellectual property agreements to encourage the exchange of innovations between government and private entities.
- Encourage joint ventures or consortia formation between government agencies, private companies, and academic institutions to tackle larger-scale space projects collaboratively.

These initiatives would cultivate a robust network of SMEs, startups, major industry partners and government in the space sector. Implementation of these initiatives would involve the establishment of an advisory committee. Comprising representatives from government, industry, and academia, this committee would ensure a comprehensive and inclusive approach.

By adapting successful international models to the Australian context, the Agency, in collaboration with the Foundation, can foster effective joint space initiatives. This initiative seeks to enhance Australia's competitiveness on the global stage and advance its space capabilities, positioning the country as a significant player in the global space arena and leveraging innovative technologies for commercial use.

Recommendation 3: Strengthen Australia's space entrepreneurialism through joint expertise and funding: time for a National Space Innovation Fund?

Australia ranks 62 out of 64 countries when it comes to entrepreneurship as proposed by *Australian Financial Review* in 2023, due to low rankings around ideas and innovation stemming from Australia's lack of 'economic complexity'.[16] The nation's current position in relation to space shows that Australia has committed approximately $360 million to grow its space infrastructure since 2020, and the Defence Force Structure Plan commits $7-10 billion to space over the next decade.[17,18] These are steps in the right direction for Australia's space industry, however if a stronger space sector is to develop, considerations should not just be on the supply of funds to target space companies, but on fostering an environment where space ventures can be fruitful.

This entrepreneurial environment has been shown to have a greater equilibrium response in venture capital going to ventures in which demand has shifted as opposed to supply,[19] that is, from stimulating, increasing and improving ventures that have the potential to provide worthwhile returns. This is where value-adding services can increase space venture potential in Australia via mentoring, networks and connections, and expansion capability.[20] Research from Harvard Business School found 85% of VCs identify the importance of value-adding services in their venture investment considerations.[21] Developing a stronger space network and access to specialised expertise is a necessary component to grow this industry firmly in Australia.

NASA, through its Jet Propulsion Laboratory, serves as a key investor in the US space industry, frequently advancing new companies. Similarly, ESA operates its own space incubator program, providing direct funding to early stage space ventures. Both provide funding from some of the highest levels of space expertise and networks in their respective regions.

It is proposed that Australia first develops a strong space network of successful founders, as well as business management and technical leaders that have a strong focus toward space venture success. It is recommended to seek expertise from more developed space industries outside Australia's borders, while also acknowledging the necessity of engaging with the global space market where Australia's presence is vital. The CSIRO should consider developing a strong presence to the space technology-related start-up community, having the expertise and resources to help ventures succeed.

This is in contrast to other implementations such as Australian Defence's funding toward Australia's space industry, in which there is reduced globalisation opportunities for funded ventures and often restrictions around foreign knowledge sharing. There is a strong benefit to adding space networks where founders, investors and leaders can make valuable contributions.

Therefore, in addition to the previous recommendation's government–private industry collaborations, this recommendation proposes for greater joint initiatives among space leaders (domestically and internationally) and venture funding via government grants, research grants, and private funding where there is a strong connection between funding and space venture expertise. This is something where the Foundation, the Agency, as well as the CSIRO and space, technology and industry leaders can advance a strategic initiative. This also leads to a proposal for a national space incubator program connecting industry experts and funds to potential space ventures in which demand will more greatly increase.

Recommendation 4: The Australian Space Agency should support the establishment of specialised research centres to advance key space technologies, diversifying Australia's space contributions by leveraging national strengths.

Australia's role in the global space sector demands strategic commitment, emphasising the essential need for Australia to develop and actively participate in advanced technology sectors. Australia's economy has seen a decline in economic complexity over the past decade.[22] As a result, the economy is anticipating a low annual growth rate of 2.0% over the coming decade, placing Australia in the bottom half of countries globally.[23]

To address this, strategic initiatives are essential for economic resilience and growth.[24] This recommendation advocates for the Agency to aid in the establishment of specialised space technology research centres. Internationally, specialised research centres like the European Space Research and Technology Centre[25] (ESTEC), NASA's Jet Propulsion Laboratory[26] (JPL) and the Indian Space Research Organisation[27] (ISRO) are instrumental in driving breakthroughs, propelling advancements and influencing global space capabilities.[28]

Australia's strengths in in-situ resource utilisation[29] (ISRU), satellite communications and control operations,[30] position, navigation and timing (PNT)[31], robotics and automation[32] and earth observation[33] as well as a myriad more,[34] position it uniquely within the global sector. Moreover, Australia's vast landscapes and equatorial position provide tangible benefits for space developments.[35] Furthermore, Australian space science research is already renowned, ranking 8th worldwide in both the number and calibre of space and planetary science publications.[36] These strengths emphasise the potential for Australia to find a competitive niche and benefit off the global space industry.

While current research facilities like the Advanced Manufacturing Research Facility[37] and CSIRO can and often do contribute broadly to space research,[38] specialised centres like the Australian Centre for Space Engineering Research[39] (ACSER) focus exclusively on areas like space engineering, satellite systems, and space robotics, significantly enhancing Australia's space capabilities. These centres complement the broader research institutions, providing targeted expertise, driving rapid innovation, and engaging closely with industry and policymakers to address emerging trends. By strategically filling expertise gaps and aligning with national priorities,[40] an expansion of specialised research centres could play a pivotal role in advancing Australia's strategic goals in space.

Australia is actively developing the Australian Space Manufacturing Network (ASMN) to establish new space manufacturing and launch facilities.[41] The ASMN as well as recent initiatives like the $19.5 million Space Infrastructure Fund[42] and the $15 million International Space Investment Grants[43] further support the establishment of specialised research centres, showcasing the

government's commitment to fostering growth and innovation in the space industry. These investments not only inject significant funding but also signal the government's dedication to enhancing competitiveness and driving innovation.[44]

The government's investments in the space industry lay the foundation for long-term strategic initiatives, bolstering Australia's competitiveness, fostering innovation, and driving economic growth.[45] Technologies derived through the targeted research of these centres would draw on Australia's unique strengths and feed back into Australian industries that heavily depend on space-derived services for communications, positioning, and imagery.[46] Collaborative efforts between government, industry, and academia, with a phased implementation, would ensure a successful implementation. The establishment of specialise research centres emerges as a strategic imperative, leveraging Australia's unique strengths to shape the future of the global space landscape, and improves the lives of Australians.[47]

Section 2: Harnessing Australia's Space Sector – Utilising Space Technologies for Earth's Challenges

Recommendation 5: The Australian Space Manufacturing Network should develop sovereign capabilities and innovation through additive manufacturing.

Australia's initiative to establish the Australian Space Manufacturing Network (ASMN) marks a significant step towards achieving sovereign capability in space manufacturing. The ASMN represents an innovative approach to building Australia's space industry. By developing testing centres, spaceports, manufacturing facilities, and research institutions, the ASMN is poised to elevate Australia's presence in the global space arena. Additionally, institutions like the Defence Science and Technology Group (DSTG) bring together interdisciplinary expertise from across Australia to address defence and national security challenges. Collaborating with entities such as the DSTG could enhance research and development efforts within the ASMN, facilitating the exploration of sovereign capability in defence and space industries.

The ASMN should leverage emerging additive manufacturing (AM) technologies to significantly enhance its strategic capabilities. AM's advantages in rapid prototyping, complex geometry constructions, and on-demand production capabilities align with the defence and space industry needs. AM offers a streamlined manufacturing process,[48,49] reducing logistical needs, which could support national security and space exploration efforts.

The reliance on undersea cables exposes the nation to risks from geopolitical tensions, environmental hazards, and the physical limitations of such infrastructure.[50,51] These challenges highlight the necessity for a more resilient and adaptable telecommunications framework.

Incorporating AM into the development of satellite systems presents a strategic pathway to fortify Australia's telecommunications infrastructure.

The deployment of satellite constellations emerges as a compelling alternative to traditional undersea cables. AM can play a pivotal role in this transition by enabling the faster, lighter and cost-effective production of satellite components and systems.[49,52] The versatility and efficiency of AM allow for the customisation and on-demand manufacturing of parts, significantly reducing the lead time and costs associated with satellite deployment.[52] Furthermore, the application of AM in allows for iterative design, continuous improvement and adaptation to emerging needs.

Self-sufficiency in manufacturing critical technologies strengthens Australia by reducing reliance on global supply chains, enhancing sovereign capability, fostering innovation, job creation, and defence readiness. By leveraging expertise throughout the industry, the ASMN can explore cutting-edge technologies like additive manufacturing for a more secure, reliable, and future-proof telecommunications network.

Recommendation 6: The Australian Space Agency should advocate for sustainable satellite lifecycle management for Earth's benefit.

The increasing number of satellite launches for communication, Earth observation, and scientific research brings forth a variety of environmental challenges such as space debris, the carbon footprint of launch operations, and the potential depletion of stratospheric ozone.[53] While space technology can benefit Earth, it's crucial to develop it sustainably, minimising harm to our planet. Sustainable satellite lifecycle management, from manufacturing to disposal, presents opportunities to mitigate these impacts and leverage space innovations for Earth's sustainability.

Key to this approach is designing satellites for energy efficiency, incorporating advanced technologies like hybrid beamforming and joint design[54] in satellite communications. These innovations reduce energy consumption and enhance operational efficiency.[55] End-of-life satellite management is vital for energy efficiency. Designing satellites for recycling or repurposing, as proposed by ESA,[56] ensures continued benefits post-mission.

Projects highlighted by the USC Viterbi School of Engineering showcase how defunct satellites can be adapted for new scientific missions or used to test emerging space technologies.[57] Further studies have explored the technical[58] and economic[59] aspects of satellite recycling, suggesting that such practices could significantly contribute to the reduction of space debris and the promotion of sustainability within the aerospace sector. Embracing energy efficiency, sustainable materials, and recycling in satellite operations aligns with global environmental goals[60] and positions Australia as a leader in sustainable space practices.

By championing these initiatives, the Agency could drive groundbreaking advancements that merge space exploration with sustainability, inspiring a future where space and Earth's preservation harmonise. Furthermore, by incentivising businesses through financial stimulus, streamlined regulation, and sustained market commitment,[61] the Agency can play a pivotal role in mitigating the space debris problem while simultaneously fostering national economic growth. This initiative not only promotes sustainable practices in space but also aligns with broader environmental and economic goals on Earth.

Recommendation 7: The Australian Space Agency should promote initiatives for healthcare research in space, investigating the impact of extreme conditions on human physiology to develop mitigative solutions and enhance healthcare.

Health research in space presents a unique avenue for advancing our understanding of biological processes and fostering innovative solutions with prospects for both space exploration and terrestrial healthcare. Space research contributes significantly to health research.[62] Repurposing space technologies presents an opportunity to enhance healthcare domains, offering new potential and creating innovative solutions to complex medical challenges. To fully harness this, an initiative to advocate for exploring and increasing funds for healthcare research projects in space should be implemented. By aligning these efforts, advancements in medical research, telemedicine, and healthcare delivery would be accelerated.

Establishing a platform or initiative that allows for the connection of professionals from both the healthcare and space sectors would foster greater joint research projects, facilitating technology transfer, and encouraging a robust exchange of knowledge. To kickstart these efforts, increased conferences similar to those conducted by the UN/WHO,[63] specific to the health-space intersection could highlight accessible solutions to current space-assisted medicinal technologies, like advancements in tissue engineering utilising microgravity,[64] and innovations from PhD students and small companies.

Designed to unite researchers, healthcare experts, and leaders in the space industry, this effort would promote collaboration and shared investment by obtaining a diverse selection of insights. Further, government officials, given their role in funding and policy-making, may also see value in addressing medical challenges, establishing a network that effectively amplifies the impact of health research in space.

The micro-gravitational environment of space provides a platform for studying human physiology under unreplicable conditions on Earth.[65] Observations into changes in the brain structure and connectivity in astronauts provide a model for studying neurodegenerative processes and developing neuroprotective therapies, but further studies are necessary to identify, monitor, and mitigate spaceflight associated neurological changes.[66] The heightened

oxidative stress[67] experienced in space due to microgravity presents an opportunity to study the cellular processes involved in conditions like Alzheimer's and Parkinson's[68] diseases, contributing to research in managing and understanding their development.[69]

The research into cellular processes in space also offers consequential perspectives for other space exploration projects such as future Mars exploration. Utilising various current space technologies in collaboration with research industries offers a potential avenue to fast-track the discovery and innovation that could revolutionise the healthcare industry. The Agency could collaborate with Australian pharmaceutical and biomedical research companies to conduct this research.

Recommendation 8: The Department of Agriculture, Fisheries and Forestry should implement precision agriculture and environmental monitoring using satellite imaging, for farmers to predict weather patterns and manage pests more effectively.

In today's fast-growing farming landscape, integrating satellite imaging and analytics is a must. By utilising the power of satellite technology, farmers can have access to necessary information allowing informed decision-making. Integrating new resources like real-time crop monitoring and precise point positioning can introduce a new era of sustainable agriculture.

There are three main ways in which satellites can aid farmers; mapping: understanding how large areas of land can be used and optimised for different types of agriculture; measuring: plugging satellite data into complex algorithms to provide measurements on a range of properties such as yield and crop growth stage; and monitoring: observing landscape and weather trends to see how the land has developed or spot changes in rainfall and drought patterns.

A paper published by the World Economic Forum in collaboration with McKinsey and Company[70] stated that the identification of early-stage pests by hyperspectral and optical satellite imagery, if applied at scale, could help salvage up to 0.8 billion tonnes of crops annually.[71] By using satellites to monitor agriculture, water usage can be reduced by 5%-10% and food waste reduction could add $150-175 billion in economic value for producers.[71]

Space-based remote sensors collect data including land and sea surface temperature, cloud and vegetation properties and imagery from optical, hyperspectral and multispectral domains[72] which can drive advanced analytics to provide insights in the field and across farming seasons.[71] These cases tend to use unmanned aerial vehicles (UAVs or drones) however, satellites offer advantages at scale and eliminate the need for large, ground operations.

It would be beneficial for the government and investors in the agricultural community across the globe to collaborate with satellite providers and data analytics firms to establish a platform that

provides closer to real-time satellite imagery and data analytics tools tailored for precision agriculture applications.

Recommendation 9: Establish a program to replace the National Space Mission for Earth Observation to obtain satellite data and address climate change impacts, for instance, in the Great Barrier Reef.

Satellite data is a heavily implemented data-collection strategy across the globe for many purposes including the tracking of wild animals,[73] drought and flooding predictions,[74] and crop monitoring. However, Australia is becoming growingly dependent on global partners to access this data which could have been prevented with the establishment of the National Space Mission for Earth Observation (NSMEO). After the project was cancelled due to budget repairs, Australia remained at risk of losing this data upon rising geopolitical tension.[75] Moreover, the Australian GDP has also been investing $5 billion into outsourcing satellite data and remote sensing outlets which could be invested elsewhere.[75]

Satellite data can provide assistance to Australia's environmental causes such as observing and acting upon water quality fluctuations and coral bleaching across the Great Barrier Reef. Satellite data would reduce surveying work for the Reef, which covers 2000 km along the east coast of Australia.[76] Satellite data has been previously implemented in similar contexts, for example a collaboration between ACCIONA and NASA to acquire satellite data for seawater quality monitoring around ACCIONA's desalination plants in the Middle East.[77]

Proposing a replacement of the NSMEO program would allow Australia to become an independent space entity and retrieve satellite data to target a range of projects, especially those specific to Australia. Moreover, this initiative would allow for developments in new research ideas proposed by students looking into data analysis or satellite innovation.

This proposal is primarily targeted to the Department of Industry and Science and other Australian space organisations ranging from start-ups to well-established businesses, encouraging research and development in space technologies, ultimately leading to profit for investors in the future. Other businesses involved in projects this program would address, including those for rebuilding the Great Barrier Reef, would also be a target demographic. Tax-deductible donations may also entice Australian citizens to pitch in to the development of a new NSMEO program. Investment and encouragement from Australian citizens, could lead to developments in Australian space exploration and reduce dependency on other nations for data.

Recommendations

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Recommendation 1: The Andy Thomas Space Foundation should expand and develop its Kids in Space Program to focus on the senior secondary school level.

Recommendation 2: The Australian Space Agency, with collaboration from the Andy Thomas Space Foundation, should develop a structured collaboration framework between government and private space industry for effective joint space initiatives.

Recommendation 3: Strengthen Australia's space entrepreneurialism through joint expertise and funding: time for a National Space Innovation Fund?

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