



2023 ASTRA WHITE PAPER - ACACIA



Produced by the Astra Program



Sponsored by

 **NORTON ROSE FULBRIGHT**

FROM THE OUTBACK TO OUTER SPACE

Developing Australia's Human Spaceflight Capabilities

Contributors: Artur Cichocki, Emmanouil Vourvahakis, Gemma Collins, Girisha Puri, Harjot Kaur, Madoc Cottle, Maria Krikeli, Rahul Chaudhary, Richard Liu, Thomas Cook, Vicky Wang

Team Coordinators: Joe Andrew, Umair Muhammad

Program Coordinator: Jennifer Williams

Introduction

Almost 70 years ago, Australia's involvement in space activities focused on the Apollo program and sounding rocket launches in Woomera. Since then, Australia's space capabilities have grown, with the development of ground stations for space debris tracking and Global Navigation Satellite Services (GNSS). To-date, three Australians have been sent to outer space, with Katherine Benell-Pegg and Meganne Christian set to be the next. All of these astronauts, however, have been trained or launched by overseas space programs.¹

Human spaceflight programs (HSF) directly yields significant scientific, technological, medical, and environmental advancements for participating nations.² These include employment generation in engineering and advanced manufacturing; expansion in education and training pathways; greater opportunities for bilateral and multilateral collaboration, and improved healthcare, environmental, and security outcomes.³

Australia requires a whole-of-government (WoG) approach to the implementation and sustainment of a HSF program that recognises the importance of public-private cooperation,⁴ international collaboration, and sovereign capability investment. Sustained investment into a HSF program has the potential to significantly benefit Australia's economy and society by igniting innovation, supercharging domestic research and development, and inspiring future generations of Australians.



Methodology and Assumptions

This paper was written by Astra Program participants who come from diverse educational, cultural and professional backgrounds. Over a 4 month period, recommendations were developed based on discussions with Subject Matter Experts (SME's) to discuss the current political, financial, social and economic climates in Australian and international space industries. SME's came from Norton Rose Fulbright (NRF), Airbus Defence and Space, the Australian Space Agency (the Agency), and Saber Astronautics. Participants reviewed documents including international space treaties, inquiry reports, regulatory reform programs and research papers. Benefits, risks, and costs of an Australian HSF program were analysed and quantified.

Topic 1: Investments in Technology and Research

Australia must prioritise research in areas with land-and-space-based applications to yield tangible benefits for Australia's economy and society. As an Australian HSF program will likely be unsuccessful without robust public-private cooperation, the government should consider ways to commercialise space-based research for industry application.⁵

Recommendation 1: The Agency should establish a pipeline for organisations to conduct experiments in space and use Australian space-based assets

The Agency's astronauts operating on any allied government or commercial space station have the opportunity to carry out research useful to both the government and the Australian industry. Aside from research already deemed critical by the Agency, any remaining resources that astronauts have in space can be allocated to commercially useful research.⁶ This can be achieved by selling use of those research resources that are available to Australian companies.

Selling Australian astronauts' time on a space station benefits Australian companies who are unable to afford access to current HSF missions. While some companies overseas are able to fund their own HSF missions,⁷ there is no Australian company or government program⁸ currently able to provide this capability domestically.⁹ Offering access to a microgravity research lab to Australian companies enables innovation in critical space sectors, such as medicine and manufacturing. This prevents Australian companies from falling behind in key innovative areas.

Access to an Australian microgravity lab will increase demand and would allow for a greater share



of Australia's HSF spaceflight program to become privately funded. Space commercialisation has demonstrated a clear and relatively consistent demand for access to microgravity research environments.¹⁰ As demand rises and industry pays for a greater share of Australian activity in space, as is already happening in the United States,¹¹ pressure on the Australian government will reduce to create a more economically sustainable space ecosystem.

Recommendation 2: The Australian Government, in collaboration with the Agency, universities, and Australian space primes, should invest in space debris management, medical advancements, and remote mining technology

Despite adopting technologies to protect space-based critical infrastructure,¹² Australia's space-based assets are still prone to collision events from space debris, which present a recognised risk to both crewed and uncrewed spaceflight.¹³ This creates a cost-burden for Government and business operators due to the risk of losing the country's space-based capabilities which have already been estimated to AUD \$6.4 billion for 2022-2023.¹⁴ Reducing the risk posed by space debris through HSF assistance would ensure the continued viability of Australia's infrastructure in space.

On-orbit refuelling and repairing using recycled materials from space debris have already been considered by the National Aeronautics and Space Administration (NASA)¹⁵ and the European Space Agency (ESA).¹⁶ The Australian Government is already investing in a circular economic model that is estimated to increase GDP by \$23 billion AUD in the next two years and which could feasibly be implemented in space.¹⁷ Applying this technology in space, assisted by HSF and remote operations robotics, has the potential to reduce a well-known risk (i.e. space debris) for space operators and businesses. This will provide economic benefits in space manufacturing (including cost reductions of nearly 50%)¹⁸ whilst extending the lifespan of space technology from 5 years to 11 years¹⁹. The emerging technologies²⁰ arising from utilising the space debris in HSF missions could be implemented in Australia's terrestrial recycling systems (i.e. raw metals) to increase their growth revenue.²¹ The benefits from the space debris recycling²² and on-orbit services will increase Australia's credibility to international markets and improve long-term space capabilities.

There are also immediate, land-based societal and economic benefits associated with improving medical research in space. Investment in space-based medical research such as sun protection, air purification and waste and water management, are beneficial to Australians generally.



Specifically, improvements to remote robotic surgery including latency²³ and scale reduction are necessary for the technology to be applied in long-term manned space missions.²⁴ The same technological improvements will also make remote surgery accessible to the 28% of Australians living in rural areas.²⁵

The Agency should continue to invest in technologies required for the remote extraction of space materials for use in space. Investments such as the Trailblazer program²⁶ utilise Australia's world-leading expertise in remote robotic mining.²⁷ Resources extracted in space may eventually be used to support long-term manned space missions.²⁸ Australia should not invest in space mining for resources to be used on earth as propulsion technology is currently unfeasible for this application.²⁹

It is recommended that the Agency, in collaboration with universities and governmental and non-governmental organisations, should support the establishment of an HSF program by investing in cutting-edge research in space debris management, medicine and research that could increase Australia's space export revenue.³⁰

Topic 2: Politics and International Relations

To develop a domestic HSF program, it is crucial that Australia reaches out to its international partners and engages in technology, knowledge, and labour exchange through negotiation and collaboration.

Recommendation 3: The Australian Government, through the Agency, and in collaboration with NRF, should leverage its geographical location and capabilities to acquire technologies and expertise for a HSF program.

The most efficient method of establishing a domestic space sector is partnering with larger organisations such as NASA, ESA and JAXA.³¹ Australia must have domestic capabilities that can be shared to gather overseas technologies and knowledge for a domestic HSF program. Australia's favourable geographic location and technical expertise in satellite imagery and communications present viable options for negotiating with larger space agencies.³² Australia also remains in a unique position to develop the direction and level of involvement in the space industry, and can leverage domestic comparative advantage.³³



Australia's proximity to the equator offers lift advantage and access to sun synchronous orbits for launches. This positions Australia well for satellite communications and control purposes and for implementation of space situational awareness (SSA) technologies.³⁴ Using the expertise of multinational law firms who have market expertise in procurement and international technology partnerships, such as NRF,³⁵ the Agency can work through international bilateral and multilateral partnerships and negotiate use of Australian assets, including the unique geographic location.

Australian companies are making significant strides in developing Australia's comparative advantage and technological capabilities in space. Neumann Space are producing solutions for satellite propulsion and space debris management that assist in on-orbit recycling and establishing a circular economy system in space.³⁶ Myriota have developed low Earth orbit nano satellites that provide Internet of Things services to millions of users, while also greatly reducing ground costs.³⁷ Leveraging technologies like these prove that Australia has space and production capabilities of real utility and value to the global space industry. Investment in the technologies outlined in Recommendation 2 will provide Australia with further technological capabilities, incentivising collaboration with other space-capable nations.

Recommendation 4: The Australian Government, in collaboration with NRF, should seek partnerships with countries in the Indo-Pacific region to further establish economic and political ties

The Indo-Pacific region represents an immense opportunity for Australia to develop HSF capabilities. Australia, as a partner of the Indo-Pacific,³⁸ can act as a hub for knowledge and labour exchange between countries. This enables Australia to facilitate a pathway for other established space-capable nations to collaborate with the Indo-Pacific.

Multiple Indo-Pacific countries, including Malaysia, New Zealand, the Philippines, Singapore, and Vietnam, have announced plans to begin developing space technologies.³⁹ Some of these governments, such as Indonesia, plan to be able to launch sovereign satellites by 2040.⁴⁰ Forming economic and political partnerships with these nations while their space industries are in their infancy would provide Australia with an opportunity to develop regional growth in the Indo-Pacific. This would strengthen this region on the international stage and obtain pathways for knowledge and technological exchange.



Australia should advance the Association of Space Entrepreneurs in the Indo Pacific (ASEIP) initiative, a proposed arrangement to boost scientific and business cooperation between Indo-Pacific countries.⁴¹ To fully develop the legal and political framework that this collaboration would entail, it is essential that the Australian Government work with firms such as NRF. As a multinational law firm with offices in countries in the Indo-Pacific,⁴² NRF offers the capability to provide important contextual information regarding the economic and legal landscapes in these countries. Australia's investment in Indo-Pacific relationships and the ASEIP is essential in developing a domestic HSF program and providing an exchange of technology and knowledge.

Topic 3: Education and Astronaut Training

Investing in education is investing in societal growth. New vocational education pathways are required to expand the certifications currently available and ensure all current and future industry space investments are sustainable through a qualified workforce, laying the groundwork for an Australian Astronaut Corps.

Recommendation 5: The Australian Government should encourage Technical and Further Education (TAFE) institutions to create space career pathways

Vocational education and training (VET) institutes, including TAFE, should develop new courses catering to the space industry and create pathways to space industry employment and a bridging course to further educational pathways.⁴³ VET courses are cost-effective and efficient ways to teach applied technical skills in trade based crafts. Tradespeople have been identified as critical to space manufacturing⁴⁴ and can help grow the Australian space sector.⁴⁵ 57% of those tradespeople are VET trained certified⁴⁶ but there is currently no vocational program teaching space-specific trades.⁴⁷

The first step towards establishing the necessary knowledge base amongst tradespeople is upskilling the existing workforce through reclassification regimes⁴⁸ similar to those available to Victorian electricians moving into the solar energy industry.⁴⁹ Entry-level courses should then also be aimed at young students to learn in-demand skills for space manufacturing.⁵⁰ But low apprentice wages and cuts to TAFE funding are deterring future students from enrolling⁵¹ and exacerbating labour shortages.⁵² TAFE funding should be increased to provide these new space-related courses tailored to current and proposed project needs.⁵³ These courses would



reinvigorate interest in vocational courses, alleviate labour shortages, improve graduate employment rates,⁵⁴ and contribute to the Australian space sector.

The Australian Space Manufacturing Network (ASMN) is a consortium working to increase Australia's sovereign supply chain, manufacturing, launch and space capabilities.⁵⁵ The ASMN has proposed to build manufacturing and launch facilities in Queensland.⁵⁶ With the launch industry contributing 20% to the \$12 billion AUD space-industry goal in 2030,⁵⁷ ASMN members and TAFE Queensland, should tailor their courses to ASMN's projects. The University of Adelaide has already begun integrating ASMN opportunities into their electronic engineering programs.⁵⁸

Courses should cover general technical basics, similar to those already available,⁵⁹ in a space context.⁶⁰ Course content should include topics like construction of space facilities, electronic circuit design and repair for robotics and communication devices, fabrication and precision welding skills.⁶¹ Theoretical courses should be designed to teach awareness of space operations from an Australian and Indo-Pacific scope to develop a non-technical space industry workforce. Content would include space governance, space sustainability, and the global and Australian space economy. Success in these programs could also inspire other vocational education providers to create their own courses.⁶² Investing in VET AND TAFE education will increase the aerospace workforce in building the infrastructure required to support an HSF program and training facilities.

Recommendation 6: Establish an Australian Astronaut Corps as a unit of the Agency to select and prepare astronauts

An Australian Astronaut Centre should be formed with the assistance of Australian primes, industry bodies, and educational institutions like the ASMN, which are already building HSF capabilities. The centralised facility will primarily provide astronaut-specific training⁶³ for applicable Australians and, once well established, later include students re-qualified in their trade to be space-ready and university graduates for Earth-based space operations. While the primary focus will be a national astronaut program to mimic other international agencies, this expertise would be transferred to the centre's future educational programs for both domestic and overseas applicants. Involving not only astronauts in future space-related education will promote industry recognised courses and embrace diversity, strengthening relations particularly in the Indo-Pacific region.⁶⁴



This Astronaut Centre will benefit from the expertise of Australia's state-led space hubs and academic centres for a WoG approach to achieve a multidisciplinary and coherent Australian space industry. States should follow South Australia's space centre investment and redirect focus on their specialised space-relevant hubs like Equatorial Launch Australia (ELA),⁶⁵ Canberra Deep Space Communication Complex⁶⁶ and the Australian Antarctic Program (AAP).⁶⁷ The incremental budget increase from the Agency in accordance with Recommendation 8 will support states looking to invest in their own space sector. The Corps would promote bilateral and multilateral cooperation with Australia's Indo-Pacific partner mentioned in Recommendation 4 through astronaut exchange and training programs.

Two sites are viable locations to conduct some of the Corps activities: South Australia Space Industry Centre in Adelaide,⁶⁸ Australia's current industrial home and tech centre of space,⁶⁹ or in Queensland, a home of rocketry and launch sites, and is under development by the ASMN.⁷⁰ Corps sites should collaborate with established space stakeholders to serve the Australian space industry.

Astronaut training would involve specific launch exercises at the Arnhem Space Centre, ELA, Whalers Bay Orbital Launch Complex⁷¹ and future launch site Bowen Orbital Spaceport in Abbot Point, Queensland.⁷² Participant involvement on a launch complex and with its supporting services will deepen rocket launch knowledge. Another component of training would include exercises in harsh and isolated environments with the AAP⁷³ and the Tasmanian Government. Corps participants would install and maintain remote infrastructure and conduct science experiments in inhospitable areas,⁷⁴ similar to training analogues conducted by other international space agencies.

Topic 4: Legislative and Budgetary Changes

The development of a successful Australian HSF program is contingent upon a review of the statutory basis of the Agency and a gradual and sustained increase in its budget. In considering these changes, it is imperative that the Australian Government engage with stakeholders across Australia's space sector to ensure that their diverse expertise and perspectives are adequately considered. Establishing the Agency as an independent statutory authority and improving its



ability to grow and expand its expertise will ensure that it can successfully lead and manage the complexity of an Australian HSF program.

Recommendation 7: The Department of Industry, Science and Resources should publish a consultation paper to inform the development of the purpose, scope, and functions of the Agency as a statutory authority.

The Agency is a non-statutory, WoG entity within the Department of Industry, Science and Resources (the Department). The Agency is governed by the Australian Space Agency Charter and provides a strategic overview of its purpose, values, roles, responsibilities, and governance structure.⁷⁵ Establishing the Agency as an independent statutory authority has widespread support across government and industry stakeholders. This will improve the Agency's coordination of space-related matters across government, bolster industry confidence by making the Agency a permanent entity, and enhance the Agency's ability to support an agile regulatory environment in Australia's space sector.⁷⁶

The Department should publish an Australian Space Agency Consultation Paper to guide the development of the Agency's purpose, scope, and role as a statutory authority. An open consultation process with Australian space primes and legal experts in the space sector, such as NRF, will ensure that any proposed changes to the statutory basis of the Agency is well-informed by various stakeholder perspectives.⁷⁷ The Consultation Paper must communicate the expected return on investment of an Australian HSF program for Australia's economy and society, especially considering the government's commitment to spending restraint in the October 2022 – 2023 Budget.⁷⁸ It should also outline a proposed regulatory regime for Australia's HSF program to minimise possible regulatory overlap with other relevant Commonwealth entities, like the Civil Aviation Safety Authority. Engaging with relevant government and private sector actors in Australia's space sector will ensure that the Agency's implementation of Australia's HSF program is better informed by a rigorous understanding of private sector capabilities and potential opportunities for public-private cooperation.



Recommendation 8: The Australian Government should increase the Agency's budget by 15% year-on-year over the next 10 years.

The Agency's annual budget of \$17.1 million AUD lags behind that of other Organisation for Economic Co-operation and Development (OECD) space agencies like the Canadian Space Agency at \$437 million AUD⁷⁹ and Turkish Space Agency \$1.2 billion AUD.⁸⁰ Australian government investment in space primarily focuses on capability acquisition programs, like the \$1.2 billion National Space Mission for Earth Observation,⁸¹ the \$150 million Moon to Mars Trailblazer program,⁸² and the \$3 billion Defence Joint Project 9102.⁸³ The Australian Government should increase the Agency's budget by 15% year-on-year over the next ten years to ensure that it can successfully lead and manage the complexity of an Australian HSF program through increased investments into talent and capability acquisition programs.

While under the coordinating authority of the Agency, Australia's approach to space is spread across several government agencies and departments.⁸⁴ A gradual approach to increasing the Agency's budget recognises the congested nature of space engagement in Australia and the need to consider various spending priorities to maximise improvements in national space capabilities. Developing a clear timeline for investment with realistic milestones to be met at each increased funding stage will improve the response to and implementation of an Australian HSF program as a long-term and sustainable government policy.



Recommendations

Topic 1: Investments in Technology and Research

- **Recommendation 1:** The Agency should strengthen public and private partnerships to establish a pipeline for organisations to conduct experiments in space and use Australian space-based assets.
- **Recommendation 2:** The Australian Government, in collaboration with the Agency, universities, and space companies, should invest in space debris management, medical advancements, and remote mining technology.

Topic 2: Politics and International Relations

- **Recommendation 3:** The Australian Government, through the Agency, and in collaboration with Norton Rose Fulbright, should leverage its advantageous geographical location and the technologies listed in Recommendation 4 to acquire essential technologies and expertise required for a HSF program.
- **Recommendation 4:** The Australian Government, in collaboration with Norton Rose Fulbright, should seek partnerships with countries in the Indo-Pacific region to further establish economic and political ties.

Topic 3: Education and Astronaut Training

- **Recommendation 5:** The Australian Government should encourage Technical and Further Education (TAFE) institutions to create space career pathways.
- **Recommendation 6:** Establish an Australian Astronaut Corp as a unit of the Agency to select, train, and prepare astronauts for Australian and international space missions

Topic 4: Sovereignty and Financial Recommendations

- **Recommendation 7:** The Australian Government should publish a consultation paper to inform the development of the purpose, scope, and functions of the Agency as a statutory authority.
- **Recommendation 8:** The Australian Government should increase the Agency's budget by 15% year-on-year over the next 10 years.



Acknowledgements

Team Acacia would like to acknowledge the support we have received from a number of organisations and individuals within the Australian space industry.

We would like to begin by thanking Norton Rose Fulbright for their tremendous support as the team's sponsor. In particular, we would like to thank Norton Rose Fulbright's Igor Kungurov, for providing his incredible insight and guidance.

We would also like to thank the following people for their support and time during the preparation of this white paper:

- Tori Tasker, Senior Space Technology Officer, Australian Space Agency
- Dr Christian Steimle, Program Manager Bartolomeo Mission Service, Airbus Defence and Space GmbH
- Mathias Seifert, Program Manager ISS Columbus Engineering Services, Airbus Defence and Space GmbH
- Matthias Seifert, Key Account Manager, R&T Partnerships, Airbus Defence and Space GmbH
- Martin Rowse, Australian Director of Space, Airbus Defence and Space GmbH
- Siân Cleaver, Industrial Manager, Artemis' Orion European Service Module (ESM) programme, Airbus Defence and Space GmbH
- Jason Held, Chief Executive Officer, Saber Astronautics

Without their willingness to speak to us throughout the program and answer a multitude of questions, we would not have gained the insight needed to complete this whitepaper. Each of these experts also took their time to provide us with knowledge beyond the core topic, further expanding the team's understanding of the space sector.

We would also like to thank the AYAA and Astra program committee for their time preparing the program, organising guest speakers and providing support. This program is a great introduction to the problems facing the Australian space industry. It has also provided a fantastic opportunity to learn from some of the industries' experts.



Endnotes

- ¹ Department of Industry, Innovation and Resources, Astronaut, [industry.gov.au](https://www.industry.gov.au/australian-space-discovery-centre/pathways-career-space/astronaut), accessed March 12, 2023, <https://www.industry.gov.au/australian-space-discovery-centre/pathways-career-space/astronaut>
- ² International Space Exploration Coordination Group, "Benefits Stemming from Space Exploration.", [globalspaceexploration.org](https://www.globalpaceexploration.org/?p=497), September 20, 2013, <https://www.globalpaceexploration.org/?p=497>
- ³ Canadian Space Agency, "Everyday benefits of space exploration.", [asc-csa.gc.ca](https://www.asc-csa.gc.ca/eng/about/everyday-benefits-of-space-exploration/), accessed March 6, 2023, <https://www.asc-csa.gc.ca/eng/about/everyday-benefits-of-space-exploration/>
- ⁴ Alice Klein, "Australia's first rocket is set to launch into space in April 2023.", [newscientist.com](https://www.newscientist.com/article/2347513-australias-first-rocket-is-set-to-launch-into-space-in-april-2023/), November 20, 2022, <https://www.newscientist.com/article/2347513-australias-first-rocket-is-set-to-launch-into-space-in-april-2023/>
- ⁵ Department of Industry, Science and Resources, "Australia's space projects and funding opportunities for businesses.", [industry.gov.au](https://www.industry.gov.au/australian-space-agency/space-funding-and-initiatives), accessed March 14, 2023, <https://www.industry.gov.au/australian-space-agency/space-funding-and-initiatives>
- ⁶ Global Australia, Space, [globalaustralia.gov.au](https://www.globalaustralia.gov.au/industries/space), accessed March 10, 2023, <https://www.globalaustralia.gov.au/industries/space>
- ⁷ Axiom Space, "Meet Ax-1, The beginning of a New Era.", [axiomspace.com](https://www.axiomspace.com/ax1), accessed March 2, 2023 <https://www.axiomspace.com/ax1>
- ⁸ Carsten Hirschberg, Ireen Kulish, Ilan Rozenkopf and Tobias Sodoge, "The potential of microgravity: How companies across sectors can venture into space.", [mckinsey.com](https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/the-potential-of-microgravity-how-companies-across-sectors-can-venture-into-space), June 13, 2022, <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/the-potential-of-microgravity-how-companies-across-sectors-can-venture-into-space>
- ⁹ Department of Industry, Science and Resources, "Australia's space projects".
- ¹⁰ Carolyn Belle, "Finding Elasticity In The Space Industry.", [satmagazine.com](http://www.satmagazine.com/story.php?number=947177197), February, 2016. <http://www.satmagazine.com/story.php?number=947177197>
- ¹¹ National Aeronautics and Space Administration, "Commercial Crew Program.", [nasa.gov](https://www.nasa.gov/exploration/commercial/crew/index.html), accessed March 5, 2023, <https://www.nasa.gov/exploration/commercial/crew/index.html>
- ¹² The European Space Agency, "The cost of space debris.", [esa.int](https://www.esa.int/Space_Safety/Space_Debris/The_cost_of_space_debris#:~:text=Space%20debris%20is%20expensive%2C%20and%20will%20become%20even%20more%20so&text=For%20satellites%20in%20geostationary%20orbit,higher%20than%205%E2%80%9310%25), May 7, 2020, https://www.esa.int/Space_Safety/Space_Debris/The_cost_of_space_debris#:~:text=Space%20debris%20is%20expensive%2C%20and%20will%20become%20even%20more%20so&text=For%20satellites%20in%20geostationary%20orbit,higher%20than%205%E2%80%9310%25
- ¹³ Space Debris, [britannica.com](https://www.britannica.com/technology/space-debris), <https://www.britannica.com/technology/space-debris>, National Aeronautics and Space Administration, "Space Debris and Human Spacecraft.", [nasa.gov](https://www.nasa.gov/mission_pages/station/news/orbital_debris.html), May 27, 2021, https://www.nasa.gov/mission_pages/station/news/orbital_debris.html
- ¹⁴ IBISWorld, "Satellite Communications and Astronautics in Australia-Market Research report," [ibisworld.com](https://www.ibisworld.com/au/industry/satellite-communications-astronautics/5545/), February 15, 2023, <https://www.ibisworld.com/au/industry/satellite-communications-astronautics/5545/>



- ¹⁵ National Aeronautics and Space Administration – Goddard Space Flight Center, “On-orbit Satellite Servicing Study.”, Project Report, nexis.gsfc.nasa.gov, October 2010, https://nexis.gsfc.nasa.gov/images/NASA_Satellite%20Servicing_Project_Report_0511.pdf
- ¹⁶ European Space Agency, “ESA is looking into futuristic in-orbit services: recycling satellites.”, blogs.esa.int, September 9, 2019, <https://blogs.esa.int/cleanspace/2019/09/09/esa-is-looking-into-futuristic-in-orbit-services-recycling-satellites/>
- ¹⁷ KPMG economics, “Potential economic pay-off of a circular economy.”, KPMG.com.au, April 28, 2020, <https://assets.kpmg.com/content/dam/kpmg/au/pdf/2020/potential-economic-pay-off-circular-economy-australia-2020.pdf>
- ¹⁸ Iain D. Boyd, Reina S. Buenconsejo, Piskorz, Danielle Bhavya Lal, Crane, Keith, and Elena De La Rosa Blanco, “Exploring Benefits of On-Orbit Manufacturing and Assembly.”, On-Orbit Manufacturing and Assembly of Spacecraft, Institute for Defense Analyses, Jstor.org, September 1, 2017, <http://www.jstor.org/stable/resrep22854.5>
- ¹⁹ Chris Gebhardt, “Mission Extension Vehicles succeed as Northrop Grumman works on future servicing/debris”, nasaspaceflight.com, May 7, 2021, <https://www.nasaspaceflight.com/2021/05/mev-success-ng-future-servicing/>
- ²⁰ Kumar Mariappan, VRS, Weddell, SJ, Muruganandan, VA, Jeung, I-S, Theoretical studies on space debris recycling and energy conversion system in the International Space Station, Engineering Reports, 2021; 3:e12317, <https://doi.org/10.1002/eng2.12317>
- ²¹ V Maiwald, Schubert, D., Quantius, D. et al. From space back to Earth: supporting sustainable development with spaceflight technologies, Sustain Earth 4, 3 (2021), <https://doi.org/10.1186/s42055-021-00042-9>
- ²² Ryan Leonard, Ian D. Williams, “Viability of a circular economy for space debris.”, Waste Management, Volume 155, 2023, Pages 19–28, ISSN 0956-053X, <https://doi.org/10.1016/j.wasman.2022.10.024>
- ²³ RK Orosco, Lurie B, Matsuzaki T, Funk EK, Divi V, Holsinger FC, Hong S, Richter F, Das N, Yip M, “Compensatory motion scaling for time-delayed robotic surgery.”, Surg Endosc, 2021 Jun;35(6):2613–2618, <https://doi.org/10.1038/s41526-021-00183-3>
- ²⁴ D. Pantalone, Faini, G.S., Cialdai, F. et al.”, Robot-assisted surgery in space: pros and cons, A review from the surgeon’s point of view.”, npj Microgravity 7, 56, 2021, <https://doi.org/10.1038/s41526-021-00183-3>
- ²⁵ Australian Institute of Health and Welfare, “Rural and remote health,” aihw.gov.au, Updated July 07, 2022, <https://www.aihw.gov.au/reports/rural-remote-australians/rural-and-remote-health>
- ²⁶ Department of Industry and Resources, “Moon to Mars: Trailblazer program now open,” industry.gov.au, 7 December 2021, <https://www.industry.gov.au/news/moon-mars-trailblazer-program-now-open#:~:text=The%20over%20will%20head%20to,support%20future%20missions%20to%20Mars.>
- ²⁷ AROSE, “Fugro opens new remote operations centre for space resources, arose.org.au, 3 November 2022, <https://www.arose.org.au/news/fugro-opens-new-remote-operations-centre-for-space-and-resources/>



²⁸ Massachusetts Institute of Technology, "A possible new future alternative to land mining.", web.mit.edu,

<https://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/asteroids.html>

²⁹ D. Rochmyaningsih, "Don't distort policy in the name of national pride.", Nature 523, 257, 15 July 2015, <https://doi.org/10.1038/523257a>

³⁰ Asia Pacific Aerospace Consultants Pty Ltd. "Inquiry into Developing Australia's Space Industry". Submission to The House of Representatives Standing Committee on Industry, Innovation, Science and Resources. aph.gov.au. Published February 12, 2021.

<https://www.aph.gov.au/DocumentStore.ashx?id=87d3016d-ddfd-419d-92d2-96d5db7a7106&subId=702743>

³¹ Department of Industry, Science and Resources. Australian Space Civil Strategy 2019–2028.

industry.gov.au. Published April 1, 2019. <https://www.industry.gov.au/publications/australian-civil-space-strategy-2019-2028>

³² Lisa Jarrett; Flentje, Warren. "Space - A Roadmap for unlocking future growth opportunities for Australia." Australia: CSIRO; 2018. csiro:EP189206. Published September 24, 2019.

<http://hdl.handle.net/102.100.100/86454?index=1>

³³ Australian Academy of Science. "Position statement–Australian space industry." science.org.au.

<https://www.science.org.au/supporting-science/science-policy/position-statements/statement-space-industry>

³⁴ Acil Allen Consulting. "Australian Space Industry Capability." Report to Department of Industry, Innovation and Resources. industry.gov.au. October 2017.

https://www.industry.gov.au/sites/default/files/2019-03/australian_space_industry_capability_-_a_review.pdf

³⁵ Norton Rose Fulbright. Sourcing and Technology. Nortonrosefulbright.com.

<https://www.nortonrosefulbright.com/en-au/global-statements/legal-notice-and-disclaimers>

³⁶ Neumann Space. "Space Sustainability." Published August 1, 2022.

<https://neumannspace.com/space-sustainability/>

³⁷ Myriota. Published March 3, 2023. <https://myriota.com/>

³⁸ Cameron, Hill. "Australia in the 'Indo-Pacific' century: rewards, risks, relationships." Parliament of Australia. Aph.gov.au.

https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/IndoPacific

³⁹ Deden H. A. Alfathimy, Yunita Permatasari, Euis Susilawati, Dini Susanti, Shinta R. Diana, Joko Susanto & Aristyo R. Darmawan. "The Indo-Pacific and Space Diplomacy: Published 3 October 2022. Opportunities and Challenges, Astropolitics.", 20:1, 43–63,

<https://doi.org/10.1080/14777622.2022.2081076>

⁴⁰ M. Bruce. "An Indo-Pacific Space Security Alliance Is What Australia, the Indo-Pacific, and the World Need." aasyp.org. Published December 17, 2020.

<https://aasyp.org/2020/12/17/an-indo-pacific-space-security-alliance-is-what-australia-the-indo-pacific-and-the-world-need/>



-
- ⁴¹ The Economic Times. "Space sector associations from Indo-Pacific join hands to explore new opportunities." [economictimes.indiatimes.com](https://economictimes.indiatimes.com/news/science/space-sector-associations-from-indo-pacific-join-hands-to-explore-new-opportunities/articleshow/97382593.cms). Updated January 27, 2023.
- ⁴² Norton Rose Fulbright. Global Coverage. [nortonrosefulbright.com](https://www.nortonrosefulbright.com/en/global-coverage).
- ⁴³ Study Australia. Vocational education. 2023. [studyaustralia.gov.au](https://www.studyaustralia.gov.au/english/study/vocational-education#:~:text=An%20Australian%20Vocational%20Education%20and,studie%2C%20including%20higher%20education%20degrees).
- ⁴⁴ Swinburne University of Technology, media release. "Give me some space tradies." [swinburne.edu.au](https://www.swinburne.edu.au/news/2022/02/Give-me-some-space-tradies/). Published February 16, 2022.
- ⁴⁵ Vanessa Chapman, "Australian Space Manufacturing Network awarded \$52 million." [spaceaustralia.com](https://spaceaustralia.com/news/australian-space-manufacturing-network-awarded-52-million#:~:text=The%20MMIC%20is%20a%20federal,number%20of%20large%20transformational%20projects) Published March 28, 2022.
- ⁴⁶ CEIC data. "Australia Employment: Technicians and Trade workers." 1986-2022. Quarterly. Person Th. Australian Bureau of Statistics. [ceicdata.com](https://www.ceicdata.com/en/australia/employment-by-sex-and-by-occupation/employment-technicians-and-trades-workers).
- ⁴⁷ CBRCityNews. "Libs call for 'space tradies' in Canberra." [citynews.com.au](https://citynews.com.au/2022/lib-s-call-for-space-tradies-in-canberra/). Published August 24, 2022.
- ⁴⁸ Australian Apprenticeships. Australian Apprenticeships Priority List. [dewr.gov.au](https://www.dewr.gov.au/download/13750/australian-apprenticeships-priority-list-factsheet/31996/australian-apprenticeships-priority-list-factsheet/pdf/en). Updated 15 December 2022.
- ⁴⁹ Solar Victoria. Technical mentoring and support. Reviewed December 9, 2022. [solar.vic.gov.au](https://www.solar.vic.gov.au/technical-mentoring-support)
- ⁵⁰ CBRCityNews, Space Tradies.
- ⁵¹ Emily Wind. "Poor pay and underfunding: why Australia's vocational training system is broken." [theguardian.com](https://www.theguardian.com/australia-news/2022/sep/28/poor-pay-and-underfunding-why-australias-vocational-training-system-is-broken). Published 28 September 2022.
- ⁵² Study Australia, Vocational education.
- ⁵³ Ruth Harrison, "Gilmour leads Regional Space Manufacturing collaboration Network." [spaceaustralia.com](https://spaceaustralia.com/news/gilmour-leads-regional-space-manufacturing-collaboration-network). Published October 4, 2021.
- ⁵⁴ Cloe Baird. "The benefits of Vocational Education and Training." [opencolleges.edu.au](https://www.opencolleges.edu.au/careers/blog/benefits-vocational-education-and-training). Published February 11, 2021.



-
- ⁵⁵ Gilmour Space. "MMIC win for Australian Space Manufacturing Network." gspacetech.com. Published March 25, 2022. <https://www.gspacetech.com/post/mmic-win-for-australian-space-manufacturing-network>
- ⁵⁶ Ruth Harrison, "Gilmour leads Regional Space Manufacturing".
- ⁵⁷ Lloyd Damp, "A sovereign space-launch capability is crucial for Australia's prosperity and security." aspistrategist.org.au. Published March 31, 2021. <https://www.aspistrategist.org.au/a-sovereign-space-launch-capability-is-crucial-for-australias-prosperity-and-security/>
- ⁵⁸ Crispin Savage. "The University of Adelaide partnership in the Australian Space Manufacturing Network." adelaide.edu.au. Published March 30, 2022. <https://www.adelaide.edu.au/newsroom/news/list/2022/03/30/the-university-of-adelaide-partnership-in-the-australian-space-manufacturing>
- ⁵⁹ Swinburne University of Technology. Engineering Apprenticeships & Metalworking Fabrication. <https://www.swinburne.edu.au/courses/find-a-course/trades-apprenticeships/engineering-turner-and-fitter/>
- ⁶⁰ CBRCityNews, Space Tradies. <https://citynews.com.au/2022/lib-s-call-for-space-tradies-in-canberra/>
- ⁶¹ Swinburne University, "Give me some space tradies"
- ⁶² Crispin Savage. "Australian Space Manufacturing Network."
- ⁶³ National Aeronautics and Space Administration. "NASA-Astronauts in Training". Published May 27, 2004. nasa.gov. https://www.nasa.gov/audience/forstudents/5-8/features/F_Astronauts_in_Training.html
- ⁶⁴ South Australian Space Industry Centre. "Funding Secured for Australia- India space collaboration." sasic.sa.gov.au. Published August 18, 2022. <https://sasic.sa.gov.au/events-news-media/news/funding-secured-for-australia-india-space-collaboration/>
- ⁶⁵ Arnhem Space Centre-Equatorial Launch Australia. ela.space. <https://ela.space/arnhem-space-centre/>
- ⁶⁶ Deep Space Network. Canberra Deep Space Communication Complex. cdsc.nasa.gov. <https://www.cdsc.nasa.gov/>
- ⁶⁷ Australian Antarctic Program. antarctica.gov.au. Updated September 19, 2004. <https://www.antarctica.gov.au/about-us/>
- ⁶⁸ South Australian Space Industry. About SASIC. sasic.sa.gov.au. <https://sasic.sa.gov.au/about/about-sasic/>
- ⁶⁹ Raveena Grover. "SA launches nation's first space centre." ia.acs.org.au. Published September 22, 2017. <https://ia.acs.org.au/article/2017/launching-the-nations-first-space-centre-.html>
- ⁷⁰ Government of South Australia. "UK space companies touch down in South Australia to fuel trade opportunities." premier.sa.gov.au. Published 2 March 2023. <https://www.premier.sa.gov.au/media-releases/news-items/uk-space-companies-touch-down-in-south-australia-to-fuel-trade-opportunities>



- ⁷¹ Hillary Mansour. "Australia is well positioned for space launches." aspistrategist.org.au. Published July 21, 2021. <https://www.aspistrategist.org.au/australia-is-well-positioned-for-space-launches/>
- ⁷² Campbell Kwan. "Queensland approves new small rocket launch site at Abbot Point." zdnet.com. Published May 19, 2021. <https://www.zdnet.com/article/queensland-to-build-small-rocket-launch-site-at-abbot-point/>
- ⁷³ Australian Antarctic Program. Application Process for jobs in Antarctica. jobs.antartica.gov.au. <https://jobs.antarctica.gov.au/living-and-working-in-antarctica/application-process/>
- ⁷⁴ Australian Antarctic Program. News and Media. "Make a world of difference: Recruitment open for jobs in Antarctica." antarctica.gov.au. Published 1 December 2022. <https://www.antarctica.gov.au/news/2022/make-a-world-of-difference-recruitment-open-for-jobs-in-antarctica/>
- ⁷⁵ Department of Industry, Innovation and Resources. Australian Space Agency Charter. Industry.gov.au. Published October 1, 2018. <https://www.industry.gov.au/sites/default/files/2018-10/australian-space-agency-charter.pdf>
- ⁷⁶ House of Representatives Standing Committee on Industry, Innovation, Science and Resources, The Now Frontier: Developing Australia's Space Industry, 24 November, 2021, https://parlinfo.aph.gov.au/parlInfo/download/committees/reportrep/024732/toc_pdf/TheNowFrontierDevelopingAustralia%27sSpaceIndustry.pdf;fileType=application%2Fpdf
- ⁷⁷ Delia Rodrigo, Pedro Andrés Amo. OECD. "Organisation for Economic Co-operation and Development. Background Document on Public Consultation." oecd.org. <https://www.oecd.org/mena/governance/36785341.pdf>
- ⁷⁸ Commonwealth of Australia. Budget October 2022 – 2023: Building a better future. budget.gov.au Published October 23, 2022. https://budget.gov.au/2022-23-october/content/overview/download/budget_overview.pdf
- ⁷⁹ Canadian Space Agency. 2022 – 2023 Departmental Plan. asc-csa.gc.ca. Published March 3, 2022, <https://www.asc-csa.gc.ca/eng/publications/dp-2022-2023.asp>
- ⁸⁰ Presidency of Strategy and Budget. 2023 Yılı Merkezi Yönetim Bütçe Kanunu Teklifi. sbb.gov.tr. Published October 17, 2022. <https://www.sbb.gov.tr/wp-content/uploads/2022/10/2023-Yili-Merkezi-Yonetim-Butce-Kanunu-Teklifi-ve-Bagli-Cetveller.pdf>
- ⁸¹ Commonwealth Scientific and Industrial Research Organisation. Media Releases and Statements. "National Space Mission for Earth Observation." csiro.au. Published March 30, 2022. <https://www.csiro.au/en/news/News-releases/2022/National-Space-Mission-for-Earth-Observation>
- ⁸² Department of Industry, "Science and Resources, Moon to Mars: Trailblazer program".
- ⁸³ Liam McAneny. "Boeing Constructs ground systems for JP 9102 Bid." spaceconnectiononline.com.au. Published December 12, 2022. <https://www.spaceconnectonline.com.au/satellites/5728-boeing-constructs-ground-systems-for-jp9102-bid>
- ⁸⁴ Davis, Malcolm. "The Australian Defence Force and contested space." aspi.org.au. Published August, 2019. <https://s3-ap-southeast-2.amazonaws.com/ad-aspi/2019-08/The%20Australian%20Defence%20Force%20and%20contested%20space.pdf>

An initiative by the



Copyright © 2023 The Astra Program

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the publisher, except in the case of brief quotations embodied in reviews. For permission requests, write to the publisher, addressed “Attention: Permissions Coordinator,” at the address below.

Australian Youth Aerospace Association (AYAA)
PO Box 4315, St Lucia South
QLD 4057, Australia
contact@ayaa.com.au

Published by the Australian Youth Aerospace Association (AYAA)
www.ayaa.com.au



Astra



AYAA