
REVIEW OF AUSTRALIA'S SPACE INDUSTRY CAPABILITY

Report from the Expert Reference
Group for the Review

MARCH 2018



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Executive Summary

Overview

Not since people first walked on the Moon has the world seen the global space industry undergo such rapid reinvention. No longer restricted to government agencies and budgets, space has become a fast-growing and fiercely competitive commercial sector.

This report sets out an ambitious strategy to triple the size of Australia's nascent space industry to AU\$10-\$12 billion dollars per year by 2030, making it a key contributor to the growth and diversification of the Australian economy. The growth of our space industry will provide an additional 10,000 to 20,000 high-level jobs across Australia, while creating a sustainable and important capability for the nation. Space is integral to how all of us communicate, locate, and see the world and underpins the ability of Australia's key sectors such as agriculture, maritime, gas, mining and transport to remain world-leading. Growing how we use space will change how we live and work in remote and regional Australia, including providing new opportunities for communication in our regional areas.

The new paradigm for space set the context for a wide-ranging review into the Australian space industry conducted by us, the Expert Reference Group (ERG), between July 2017 and March 2018. We engaged intensively with the space community in every State and Territory of Australia, and around the globe. We met with industry leaders of the space community, as well as Ministers and senior officers of relevant Government agencies, and we reviewed the activities of more than 170 companies and 34 research groups within the Australian space sector.

Our Report draws heavily on the insights and contributions we derived from these meetings and an analysis of more than 200 submissions. We sincerely thank all those who contributed their input to the ERG's review.

Central to all our work was to reflect the view of the nation, and lay out the opportunity and pathway for Australia to participate fully in the space sector.

It became clear to us from these consultations that there was strong consensus across the nation that an Australian space agency was needed to lift national and international engagement; set national policy and strategy to realise Australia's ambitions in the civil space sector; facilitate growth in the space industry sector; and inspire the nation with Australia's contribution to human endeavours in space.

An Interim Report was provided to the Minister following our nation-wide consultations. We welcomed the announcement by the Government in September 2017 of the establishment of an Australian space agency (the Agency).

We recommend that the Agency has adequate long-term funding to achieve its goals, and is established as a dedicated, ongoing, whole-of-government statutory agency. We define an Agency Charter that lays out its roles, responsibilities, and governance arrangements. The Charter also identifies the changes required for national coordination of the space community, given the increasing role of space across the broader economy and for national security.

We have highlighted the role of the Agency in securing international partnerships and supporting national activities in collaboration with State and Territory Governments, industry, academia and research institutions to facilitate the growth of Australia's space industry and research capability. In this context we recognise that the Agency should be additional to such ongoing activities, rather than usurp them.

Our Report provides a background and evidence base to the current state of Australia's space industry and the opportunity and risks for Australia. It lays out a national strategic framework and a staged

funding pathway to establish the Agency and lift national and international engagement; facilitate industry growth; and provide scope for national-scale space projects and partner missions.

Partnerships will be vital for Australia to achieve its ambitions in space. We identify critical existing and future partnerships, and outline the capability gaps and strategies to support the highly competitive civil space sector and promote Australian firms domestically and internationally.

Background

The private sector has embraced the 'New Space' agenda, contributing more than three-quarters of the US\$345 billion global space economy in 2016. This figure is expected to triple, reaching US\$1.1 trillion, by 2040.¹

We have estimated the Australian space sector economy to have been worth AU\$3.94 billion in the 2015–2016 financial year, with 88 per cent contributed by the private sector. Most of this activity came from satellite TV, broadband, and communications services, while promising contributions were made by the high-tech equipment manufacturing, and start-up and small business sectors. Australia's defence investment of nearly AU\$10 billion in the next 20 years² in space-related projects will also provide opportunities for Australian research and industry to contribute across a wide range of areas.

The Opportunity

Space will be a defining domain of human enterprise in the coming decades, and there are several key arguments for Australia to focus on capturing a larger share of the global space economy. The space industry has proven to be a reliable growth industry, and space-enabled services have boosted productivity across other sectors of the economy.

Economic development and the next generation of high-value jobs are increasingly dependent on digital data and associated services, which means space will be a crucial part of ensuring high-tech and high-paid jobs. Communicating between space and Earth requires the use of ground stations in remote areas, and space enables remote asset management in the broader economy. This means that regional and remote Australia will have a valuable role in these high-value activities.

Every day, space provides essential data for everyday activities, from banking and internet access to simply knowing where you are. Space also provides critical data that supports emergency management, planning, and weather forecasting, and inspires young people to engage in science, technology, engineering, and mathematics (STEM) domains that are crucial to underpinning Australia's position as one of the most educated and entrepreneurial nations in the world.

The link between security and space is both a challenge and an opportunity for Australia. Increased access to space and space-derived information has made capabilities such as intelligence, surveillance, and reconnaissance attainable for more countries and non-state actors. Australia has capability in secure space communications, and can play a role in supporting global rules for safe and secure operations in space, as well as developing standards for responsible behaviour in space.

Strategic Roadmap

With our unique geography that supports satellites and space missions, as well as critical awareness services such as tracking space debris, Australia is important for the realisation of global ambitions in

¹ <https://www.morganstanley.com/ideas/investing-in-space>

² Department of Defence, 2016 Integrated Investment Program, pp 36, 37, 89, 90 <http://www.defence.gov.au/WhitePaper/Docs/2016-Defence-Integrated-Investment-Program.pdf>

space. Our leadership in operating assets in remote regions also provides technologies that can be used in space.

No other industry can inspire nations quite like space, where human ambition can set its sights on interplanetary missions, colonisation beyond Earth, and the possibility of finding new life. We can dream this big because of the space-based technologies that have connected the world in unprecedented ways, and in the coming decades Australia has the opportunity to become a global leader in pushing Earth links with space even further.

Major changes in the economics of market entry offer Australia an unprecedented opportunity to invest in commercial space activities. The pathway for Australia is to capture new opportunities and meet the challenges ahead, with a primary goal of enabling the capabilities that create jobs and contribute new wealth to the Australian economy. Achieving this requires a sustainable national space industry, underpinned by world-class science and technology; a growing level of capability to design, test, maintain, sustain, enhance, and develop space-based technology; and a vibrant ecosystem of globally connected small and mature businesses. We have set an ambitious goal for Australia to triple the size of its space industry by 2030 to AU\$10–\$12 billion, and increase its share of the global space sector.

We recommend that Australia builds on its strengths in communications technologies, services, and ground stations; Space Situational Awareness (SSA) and debris monitoring; and Positioning, Navigation and Timing (PNT) to strengthen competitive advantages in the broader economy. This will also bolster the application of advanced integrated Earth observation data, and our research and development strengths in quantum communications and technologies; astronomy; planetary science; space and remote medicine; and advanced antenna and sensor technology.

We further recommend that Australia take advantage of the disruption in the space sector, and give priority to emerging frontiers where we can ‘leapfrog’ into areas of future competitive advantage. This includes the application of artificial intelligence, robotics, and big data analytics to space systems and space-derived information; next-generation communications technologies, including optical, optical hybrid, and quantum communications to enable broadband space-to-Earth communications; innovative sensors, antennae, and instrumentation; and next-generation rocket and spacecraft propulsion systems.

International Engagement

When it comes to space, Australia’s partnerships will be vital. A critical role for the Agency will be to develop umbrella agreements with key countries to enable increased Australian industry participation in joint missions and projects. Australia depends on international partnerships and agreements for access to global positioning satellites for PNT, and satellites for operational Earth observation data, weather, emergency management, and marine surveillance. Australia will be dependent on these global partnerships in the coming decades, and must continue to provide value and secure operational access. Australia is in a unique position to complement and build on the space capabilities of other nations and become a trusted partner through strong international engagement.

We recommend that Australia builds on its existing partnership and treaty-level agreements, and establishes new partnerships to increase the participation of Australian industry and research.

Enabling Industry Growth

Realising the challenge for Australia to grow its share of the global space sector requires the Government to facilitate industry growth in the following key areas: increasing Australian industry participation in global projects by securing international partnership agreements; investing in industry-led collaborative research and development in the areas of strategic priority; and making full use of the purchasing power

of Government by linking large and small business to civil space-related government projects and investments in space.

Further, Government can provide early stimulus to national infrastructure for commercial ground stations and shared test facilities as well as facilitate regulatory approvals for launch and operation of spacecraft equipment and provide clarity on Australia's international obligations.

A vital part of the pathway we recommend for Australia in space will be to share with all Australians our expanding role in space and its importance to the nation's economy, security, safety, and living standards. It will also be to strengthen the connection that young people and their parents have with space, sparking their curiosity and entrepreneurial spirit, and expanding their knowledge and interest in space, science, and technology.

Across the country, we have been inspired by the creativity, entrepreneurship, and sense of discovery of Australians. The inspiration we have gained from stories of our Indigenous elders of the constellations in our night sky, through to our track record of achievements and growing success at home and abroad, has only further emphasised the urgency with which Australia should be pursuing a greater role in the global space economy.



Dr Megan Clark AC Chair

Expert Reference Group Members:

Professor Russell Boyce

Mr Michael Davis

Professor Steven Freeland

Dr Jason Held

Dr Stuart Minchin

Professor Anna Moore

Ms Flavia Tata Nardini

Dr David Williams

Mr Trevor Power (Department of Industry, Innovation and Science ex-officio)

Mr Tom Hamilton (Department of Defence ex-officio)

Context

On 13 July 2017, the Minister for Industry, Innovation and Science, the Hon Arthur Sinodinos MP, announced a review of Australia's space industry capability to enable Australia to capitalise on the increasing opportunities within the global space industry sector (the Review). The Minister's media release announcing the Review can be found in Appendix 1.

The Review provided an Interim Report to Minister Sinodinos on 14 September 2017, which can be found in Appendix 3. On 25 September 2017, the Australian Government announced it would establish an Australian space agency (the Agency), and further tasked the Review with providing advice on the Charter for the Agency. The Government announced that the Agency would provide international representation; support to critical partnerships; coordination of a national strategy; and activities and support for industry growth. The media release can be found in Appendix 1.

Terms of Reference

The Review's 13 July 2017 Terms of Reference are as follows.

The Review of Australia's Space Industry Capability will build on the principles set out in the existing *Australia's Satellite Utilisation Policy* (2013)³ by developing a strategic framework for the Australian space sector that supports leadership, innovation, opportunity, and entrepreneurship across the sector, along with our broader national interests.

The Review will specifically address the following matters:

- identifying Australia's current industry capability and areas of comparative advantage for Australia to develop;
- technologies and practices that promote innovation in both the downstream (users of space technologies) and upstream (providers of space technologies) elements of space activities, particularly in areas of niche capability and competitive advantage;
- Australia's level of regional engagement and international collaboration, including identifying critical future and existing partnerships;
- identifying capability gaps to support the global competitiveness of Australian firms in the civil space sector;
- strategies to promote Australian firms engaged in the civil space sector, both domestically and internationally;
- risks and opportunities, including ongoing access to space data and associated infrastructure essential to our national interests;
- alignment with other sectors and Australian Government priorities, including Defence and cyber security, and meeting Australia's international obligations; and
- the most effective institutional arrangements to support the strategic direction of Australia's space industry.

Consultations with key stakeholders and State jurisdictions will be conducted as part of this Review with a focus on the matters set out above.

The Review will commence in July 2017 and will be completed by the end of March 2018.

³ <https://industry.gov.au/industry/IndustrySectors/space/Documents/Australias-satellite-utilisation-policy.pdf>

Consultation

An issues paper was published on 4 July, 2017. Meetings were held with State and Territory Government ministers and representatives. More than 240 people attended these roundtables and State Government meetings. The Review received more than 200 submissions and held an additional 63 meetings with more than 220 people informed in areas of space capability. A list of the groups consulted and the submissions received is provided in Appendix 2, which also provides a web link to the full submissions.

Analysis Work

The Review commissioned additional analysis work to support considerations in the following three areas.

Australian Space Industry Capability: to identify existing space industry capabilities in Australia; describe the alignment of space industry capabilities with other sectors in Australia; identify comparative advantages in the Australian space industry sector; and identify Australia's space industry capability gaps.

Global Space Industry Dynamics: to identify the current trends and industry dynamics in the space sector; describe 'niche' opportunities for the Australian space industry; consider the comparative capabilities of other nations; and identify the links between the space industry and other industries that exist in other nations.

Global Space Strategies and Best Practice: to identify 'lessons learned' and global best practice; provide examples of other nations' space governance arrangements; provide evidence of the efficacy of various governance models in increasing investment and expanding market opportunities; and consider the interaction between the Government and the private sector.

Appendix 7 provides a web link to the three published analysis reports.

Definition of “Space”

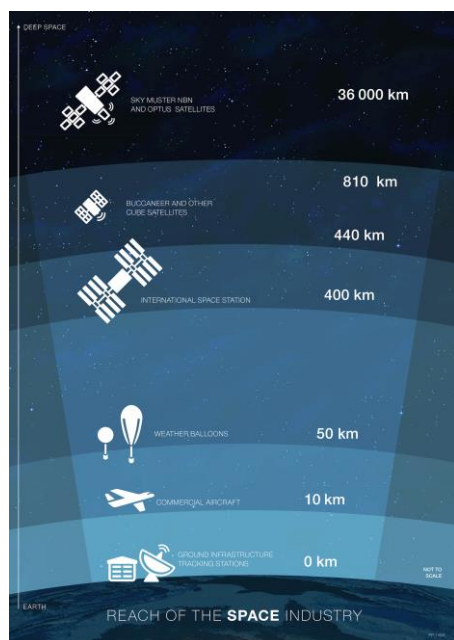


Figure 1: Diagram showing the altitudes of different space activities

Although there is no universally accepted definition of “space”, the boundary between Earth and space is most commonly delineated by the Karman Line – an altitude of 100 km above sea level and the point at which Earth’s atmosphere becomes too thin for aeronautical purposes. This threshold was used in Australia’s *Space Activities Act 1998*.⁴

In this Review, we adopt the 100 km mark as a reasonable altitude at which to demarcate “outer space”. We define the “near-space or high-altitude domain” as that existing between the altitudes of 18 km and 100 km, which takes it above commercial airline activity. This near-space region is the site of new forms of activity, such as spacecraft; balloons and drones for communications, surveillance, and positioning; and high-altitude platform stations.⁵ The scope of this Review covers activities in outer space and the near-space or high-altitude domain.

For the purposes of the Review, the OECD definition of the “space economy” has been adopted to define the broad scope of the space industry, which is the full range of activities and resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing, and utilising space.

⁴ <https://www.legislation.gov.au/Details/C2004C01013>

⁵ Satellite Working Group of the Communications Alliance Submission, p. 3; Telstra Submission p.2

http://www.commsalliance.com.au/__data/assets/pdf_file/0010/58690/SSWG-Submission-to-Australian-Space-Industry-Capability-Review.pdf

Recommendations

Strategic Priorities for Australia's Space Industry Sector

Recommendation 1:

The Agency is responsible for the development of a national space industry strategy, and that strategy gives priority to areas that build on Australia's strengths and utilise national competitive advantage and capabilities, in particular:

- communication technologies and services, satellite ground stations, and deep space communications network ground stations;
- Space Situational Awareness (SSA) and debris monitoring as part of global networks;
- Positioning, Navigation, and Timing (PNT) infrastructure to enhance the competitiveness of the broader economy including agriculture, transport, fisheries, emergency services, mining and oil and gas, and national security;
- the application of advanced integrated Earth observation satellite data for the benefit of all Australians and the broader economy, and to increase Australian exports of these services;
- research and development in areas of national strength to support Australian participation in joint space missions, space tourism, and industry applications, for example, space and remote medicine, space physics, planetary science, astronomy, quantum communications and technologies, artificial intelligence, advanced antenna and sensor technology; and
- robotics and autonomous systems for remote asset management on Earth and in space across the broader economy.

Recommendation 2:

The national space industry strategy gives importance to emerging frontiers where Australia can leapfrog into areas of future competitive advantage, including the application of artificial intelligence, robotics, and big data analytics to space systems and space-derived information; next-generation communication technologies, including optical, hybrid optical radio, and quantum communications, to enable secure, broadband space-based communications; innovative sensors, antennae, and instrumentation. Australia should also take advantage of the global space technology paradigm shift towards constellations of miniaturised spacecraft for communications and Earth observations, and next-generation rocket and spacecraft propulsion systems.

A Dedicated Space Agency

Recommendation 3:

The Government establish a dedicated, ongoing, and whole-of-government statutory agency (the Agency) to realise Australia's civil ambitions in space, and that interim arrangements are made to establish the Agency immediately. The Agency will be responsible for civil strategic policy direction setting, international representation, coordination of national civilian activities, and strategies to facilitate the growth of the Australian space industry sector as set out under the Agency Charter.

Funding for the Agency

Recommendation 4:

The Government provides ongoing, core operational funding to the Agency to enable its establishment and effective operation with additional funding for an ongoing Space Industry Development Fund once the Agency is fully operational. This Fund will invest in: international partnerships to enable increased

industry participation; industry-led collaborative research and development in the areas of strategic priority and leapfrog technologies; and support for national nodes in partnership with State and Territory governments and their industries. It will also provide early stimulus to national infrastructure such as enabling commercial ground stations and shared test facilities for satellite manufacture and equipment verification.

The Government provides scope for the Agency to bring forward for dedicated funding every three to four years, major national space projects such as satellite projects, to meet national and international terrestrial and marine needs, and to participate in discovery science missions as part of international consortia and national space competition missions.

International Engagement

Recommendation 5:

The Government extends existing partnership and treaty-level agreements, and establishes new partnerships to increase the participation of Australian industry and research, particularly by:

- strengthening partnerships in space to allow greater technology transfer and technology development in Australia;
- extending existing partnerships and treaty-level agreements, as well as promoting commercial arrangements to allow increased participation of Australian industry on missions;
- securing existing and establishing new ground stations and deep space communications centres in Australia;
- securing new partnership agreements with key space agencies and commercial partners in the global space sector, including in Asia and Oceania; and
- securing cooperation agreements for access to critical national Earth observation (EO) data, including for weather, land and oceans, and emergency and disaster management.

Industry Enablers

Recommendation 6:

The Agency works with other Government departments across a range of portfolio areas, such as agriculture, environment, and communications, to emulate the Australian Defence Innovation Hub Investment program and the US' Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs to link both large and small business to the purchasing needs for civil Government projects and investments, including the space-related investments.

Recommendation 7:

In order for commercial entities and other participants to move quickly, that the Agency facilitates regulatory approval processes for small satellite launch facilities in Australia and the launch of Australian satellites overseas, and investigates opportunities to partner with appropriate international launch providers.

Recommendation 8:

The Government gives priority to strategies that enable: active engagement with Australian schools and the broader community on global space activities; space-related training and education to improve capability; space-inspired STEM outreach; and industry-led research collaboration to underpin the space industry.

Recommendation 9:

In conjunction with the Government acting on these recommendations, we call on industry to play an important role in achieving the national goals and strategies for the Australian space industry by: investing in innovation to remain globally competitive; engaging with the Agency in setting strategic priorities; exploring partnerships with small- and medium-sized companies to participate in global supply chains; collaborating with research institutions; and supporting competitions for development of innovative technology, applications, and skills.

Background

The New Space Agenda

Not since humans first walked on the Moon have we seen the global space industry undergo such rapid reinvention.

No longer restricted to government agencies and budgets, space has become a fast-growing and fiercely competitive commercial sector, as falling launch costs and high levels of private funding continue to push the price of entry lower than it has ever been.

The private sector has wholeheartedly embraced this New Space agenda, contributing as much as 75 per cent of the US\$345 billion global space economy in 2016, while government contribution has fallen to 25 per cent.⁶

By 2040, the global space economy is expected to have tripled in size to at least US\$1.1 trillion, as demand for services escalates, and disruptive technologies such as reusable rockets and mass-produced satellites force costs down by several orders of magnitude.⁷



Figure 2: Trends in satellite mass and number over time

Figure 2a: (Left) Satellite trends since 1995. The average mass of satellites in GEO (geostationary orbit) is increasing with time, as GEO orbit slots become scarcer and the demands on GEO satellites increase and they become more complex. On the other hand, the average mass in LEO (low Earth orbit) dropped significantly in 1997, when the Iridium constellation was launched, and has been falling again in recent years as more cube-sats are launched.

Figure 2b: (Right) In LEO, large satellites (> 1,000 kg) are on the increase, but the dominant activity is the very large increase in the number of nanosatellites (< 10 kg), and to a lesser extent, microsatellites (< 100 kg), at the small end of the spacecraft scale. Graphs were constructed from data from the Union of Concerned Scientists' Satellite Database, which contains in-depth details on the 1,738 satellites currently orbiting Earth.

F2B

⁶ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 1.
<https://www.industry.gov.au/industry/IndustrySectors/space/Documents/BRYCE-Australia-Global-Space-Industry-Dynamics-Paper.pdf>

⁷ <https://www.morganstanley.com/ideas/investing-in-space>

^{F2B} <https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WnbA70uYN0s>

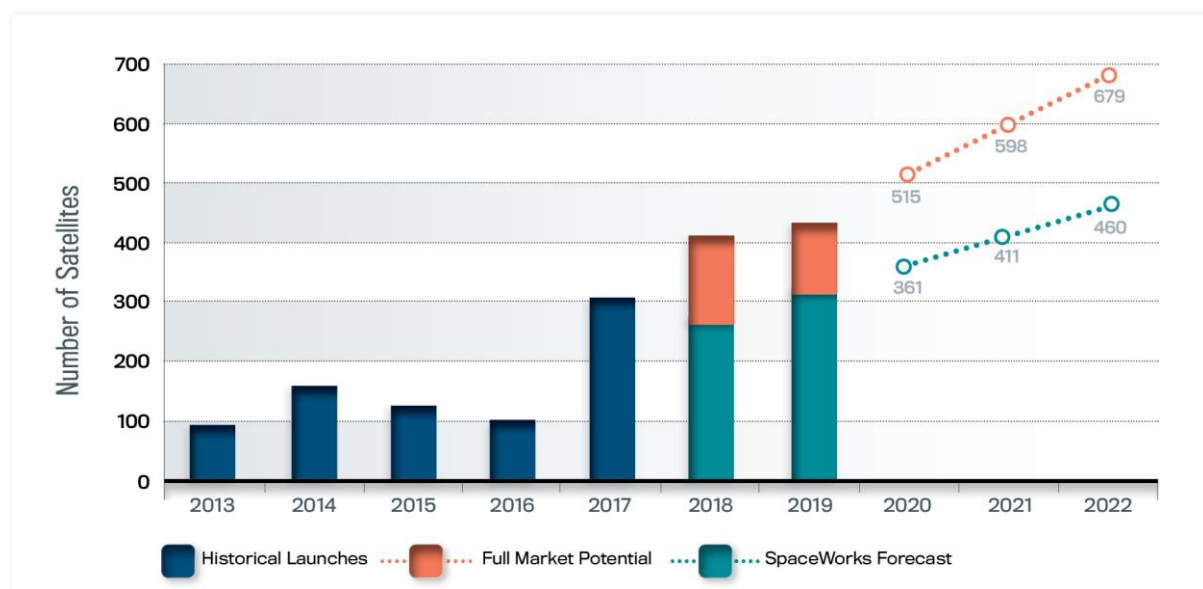


Figure 3: 2018 nanosatellite and microsatellite launch history and market forecast ^{F3}

The Global Space Economy

The commercial share of the 2016 global space economy is worth US\$262 billion per annum. Almost all of this is wrapped up in the satellite industry, which doubled in the 10 years prior to 2016.⁸

The main segments in the 2016 commercial global market were direct-to-home TV at US\$100 billion; the global navigation satellite systems (GNSS) market, including chipsets and location services, at US\$85 billion;⁹ and satellite ground equipment, which is mostly consumer equipment, at US\$60.8 billion.¹⁰

The fastest growing subsectors in the five years between 2011 and 2016 represent a small but highly successful portion of the total services market. These include EO at 54 per cent growth; mobile communications at 50 per cent growth; broadband at 33 per cent growth; and managed network services, such as Qantas' new in-flight Wi-Fi, at 35 per cent growth.¹¹

The next generation of larger and more advanced high-throughput satellites (HTS) is seeking to enable high-bandwidth applications such as TV and broadband to homes, aeroplane passengers, and cars. These satellites can double the throughput of fixed satellites while using the same radio frequency spectrum frequency bands.¹²

At present, most geostationary satellites, such as NBN Co's two Sky Muster satellites and Optus' five currently operating satellites, must be custom-built, which adds to their cost. The ability to reprogram commercial satellites in orbit would enable manufacturers to build generic satellites at a lower cost that operators can tailor to their needs through software upgrades.¹³

As outlined in Table 1, HTS performance improved 20 times between 2007 and 2017 and is projected to rise to a 100-times improvement when the first of the ViaSat-3 satellites are launched in 2019.¹⁴

^{F3} Source: SpaceWorks Nano/Microsatellite Forecast, 8th Edition <http://www.spaceworkscommercial.com>.

⁸ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 5.

⁹ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 5.

¹⁰ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 1.

¹¹ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 6.

¹² Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 16.

¹³ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 16; David Ball, Space Environments CRC submission

¹⁴ David Ball, Space Environments CRC pers. comm.

Sufficient access to suitable radio spectrum remains a key factor in the viability of consumer broadband service delivery by satellite.¹⁵ The Australian Government Department of Communications and the Arts is currently reviewing stakeholder feedback on the development of new legislation to help modernise Australia's spectrum management framework.¹⁶

Gbps = Gigabits per second. Tbps = Terabits per second.

Table 1: Performance improvements in high-throughput satellites since 2005¹⁷

Satellite	Year	Band	Throughput
Various		Ku/C	2 Gbps
IPStar	2005	Ku/Ka	45 Gbps
Wildblue-1	2006	Ka	8 Gbps
Spaceway-3	2007	Ka	10 Gbps
Ka-Sat	2010	Ka	90 Gbps
ViaSat-1	2012	Ka	140 Gbps
NBN-1a	2015	Ka	135 Gbps
ViaSat-2	2017	Ka	>200 Gbps
ViaSat-3 Americas	2019 planned	Ka	1 Tbps (1,000 Gbps)

Many New Space satellite business models have started to emerge, including Fleet Space Technologies' plan to launch the first of more than 100 nanosatellites (satellites weighing between 1 and 10 kg) in 2018 to create a global, free connectivity network,¹⁸ and Myriota's new communications platform, which will enable low-cost, direct-to-orbit Internet of Things (IoT) connectivity to industries such as agriculture, transport, maritime, and defence.¹⁹

While most of these business models are still in the development phase, telecommunications initiatives by companies such as OneWeb and SpaceX to assemble constellations of several hundred small satellites have attracted billion-dollar investments.²⁰

Beyond the satellite industry, commercial space is venturing into early stage markets for human spaceflight, launch platforms, manufacturing, and resource mining. These pursuits have all been impacted by the significantly reduced cost of launch over the past decade.

The cost of manufacturing a standard launch vehicle propulsion system constitutes approximately 70 per cent of the overall manufacturing cost for a launch vehicle.²¹ SpaceX and Blue Origin are reducing costs by developing launch vehicle systems with elements that can be refurbished and reused.²² As of

¹⁵ Satellite Services Working Group of the Communications Alliance Submission

¹⁶ ACMA submission, p.1

¹⁷ David Ball, Space Environments CRC pers. comm.

¹⁸ <https://presse.cnes.fr/en/fleet-signs-going-collaboration-french-space-agency-cnes>

¹⁹ <http://myriota.com/myriota-wins-best-new-business-sa-telstra-business-awards/>

²⁰ https://www.softbank.jp/en/corp/news/press/sb/2016/20161219_01/ ; <http://www.spacex.com/news/2015/01/20/financing-round>

²¹ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 16.

²² Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 17.

September 2017, SpaceX's Falcon 9 rocket has had 16 successful propulsive landings of its primary rocket booster, and in February 2018, the company had a successful test launch of its Falcon Heavy.

Over the next ten years several intermediate and heavy launch vehicles are expected to enter the market, including those from the European Space Agency (ESA), United Launch Alliance (ULA), and Mitsubishi Heavy Industries.²³

Space tourism ventures such as Virgin Galactic's suborbital flight program are currently scouting Earth's best top-down views in preparation for their first cohort of civilian passengers, and a framework for future exploration missions to the Moon and Mars has recently been provided by the Global Exploration Roadmap of the International Space Exploration Coordination Group, supported by 14 space agencies around the world.²⁴

These markets are highly ambitious, require high capital expenditure, and are still seeking robust business cases.

The Australian Space Industry Today

The total revenue of the space industry sector in Australia, which employs approximately 10,000 people, has previously been estimated at AU\$3–\$4 billion.²⁵

The ERG has estimated Australia's space market size in the 2015–2016 financial year at AU\$3.94 billion. This amount comprises Defence-related expenditure of AU\$175 million; non-Defence Government expenditure in agencies such as the CSIRO, the Bureau of Meteorology, Geoscience Australia, and the Australian Communications and Media Authority (ACMA) of AU\$126 million; university space-related research of AU\$44 million; and a commercial segment of AU\$3.598 billion. This is based on data from 34 of the medium and large companies and 17 of the SME and start-up companies listed in Appendix 4, and estimates from relevant Government agencies and Defence.

The ERG found that the main segments of Australia's commercial space industry in the 2015–2016 financial year were direct-to-home TV (49 per cent); satellite communications and broadband (23 per cent); ground station infrastructure and operations (8 per cent); and high-technology equipment manufacturing and services (5 per cent).

The Review identified a vibrant and competitive space community of start-ups and SMEs (Appendix 4). Three of those, Fleet Space Technologies, Gilmour Space Technologies, and Saber Astronautics, were recently listed among the top 50 most admired companies in the global space industry.²⁶

The ERG found that established Australian companies account for 87 per cent of the total Australian space market, and global space companies such as ViaSat, Northrop Grumman, Airbus, and Boeing have a significant presence in Australia.

²³ Bryce Space and Technology, *Global Space Industry Dynamics* (2017) p. 16.

²⁴ https://www.globalspaceexploration.org/wordpress/wp-content/isecg/GER_2018_small_mobile.pdf

²⁵ APAC 2015; ACIL ALLEN Australian Space Industry Capability, 2017, p. i.

²⁶ <http://www.newspacepeople.com/global-rankings-data>

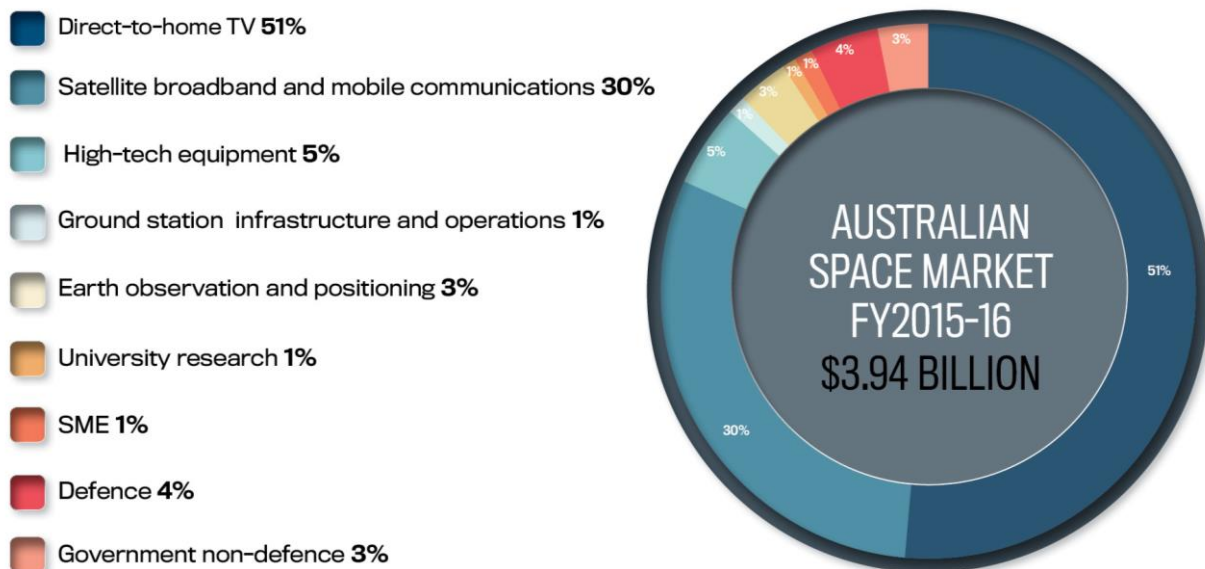


Figure 4: Australian space market estimate for FY2015-2016

NB: Direct-to-home TV market includes all cable television, direct broadcast satellite television, and IPTV catch-up services as part of the Foxtel joint venture revenue due to satellite linkages being used as part of the overall network.

Australia depends on international partnership agreements for access to all six GNSS constellations for PNT,²⁷ as well as other countries' EO satellite constellations.²⁸ These include the Japanese Himawari satellites for weather; the US Landsat and European Union's Sentinel data for EO; and SPOT data from Airbus for marine surveillance.

Geoscience Australia and the CSIRO are working with the Governments of New South Wales, Queensland, and Western Australia to establish the Copernicus Australia data hub to ensure sustained access to data supplied by the European Union's Sentinel satellites. Data from these satellites will be a key 'baseline' for Australia for the future. This project involves co-investment from all partners, and recognises the dependence that Australia's State and national Governments have on satellite data. It also highlights the need for long-term certainty of data supply to encourage industry investment in new applications.²⁹

Australia will be dependent on these partnerships for decades to come, and must continue to secure operational access while also providing value to these global partnerships through supply of ground station access; calibration and verification services; and sharing capability in data integration and application, as well as thermal or hyperspectral sensors for partner missions.

Within the next decade, Australia has the capacity to develop operational capability in marine surveillance and, further into the future, there may be a business case for Australia to provide high-end operational EO capability in selected areas. In the near-term, solidifying our global partnerships will be an important priority for the Agency.

Australia as a Prime Location for Space Innovation

Australia's unique geography covers one-third of Earth's rotation, and we are located in a region that is currently experiencing two-thirds of the global economic growth. This makes us ideally located to support satellite communications and Earth observing satellites in the Asia-Pacific region and beyond.

²⁷ ACMA Submission, p. 9

²⁸ ACMA Submission, p. 9

²⁹ Geoscience Australia Submission, p. 8

Australia's geography is important for SSA techniques that include multiple deployment of optical and infrared telescopes to determine the precise orbits of space-borne objects. In addition, with its vast radio quiet zone combined with some of the lowest levels of human population density on Earth, Western Australia's remote Murchison region is one of the best sites in the world for performing SSA via radio techniques.

Australia's global role in SSA has recently been expanded, with the relocation of the US C-band space surveillance radar at the Harold Holt Defence base in Exmouth, and the planned relocation to the same site of the optical Space Surveillance Telescope (SST) for geostationary orbits (GEOs).

Unlike countries in the Northern Hemisphere, Australia looks directly into the Solar System, making us a crucial contingent in global deep space communications systems. NASA's Deep Space Communications Centre, operated by the CSIRO at Tidbinbilla, and the European Space Agency's (ESA) Deep Space Communication Centre at New Norcia are valuable partnerships that leverage our unique location.

The ERG has established that Australia also has significant experience and expertise in ground stations, with 10 major telemetry, tracking, and satellite control stations in Australia, including the control stations of Optus, Speedcast, and Inmarsat, and for the US Government Wideband Global Satcom (WGS) and Mobile User Objective System (MUOS).³⁰

Australia's clear skies and low levels of cloud cover provide the ideal conditions for our nation to claim a significant stake in the emerging optical and optical hybrid communications systems market.

Australia also has the potential to develop launch capability for both equatorial- and polar-orbiting satellites, benefitting from vast coastlines, open water, and stable weather conditions.

In the coming years, Australia will have the opportunity to grow and diversify our economy, enter new high-growth sectors, and become a vital part of space–Earth communications.

We have the opportunity to realise human ambitions in deep space, provide high-end jobs, grow our industrial capability, and cement our place as a valued global citizen contributing to safe and secure operation in space. We also have the capacity to grow significantly in areas of productivity and competitiveness on the world stage through our engagement with space and the technologies that surround it.

Now is the time for Australia to take this opportunity to expand our role and become a leader in the global space economy

³⁰ <https://www.nbnco.com.au/blog/the-nbn-project/nbn-technology-101-what-is-sky-muster.html>

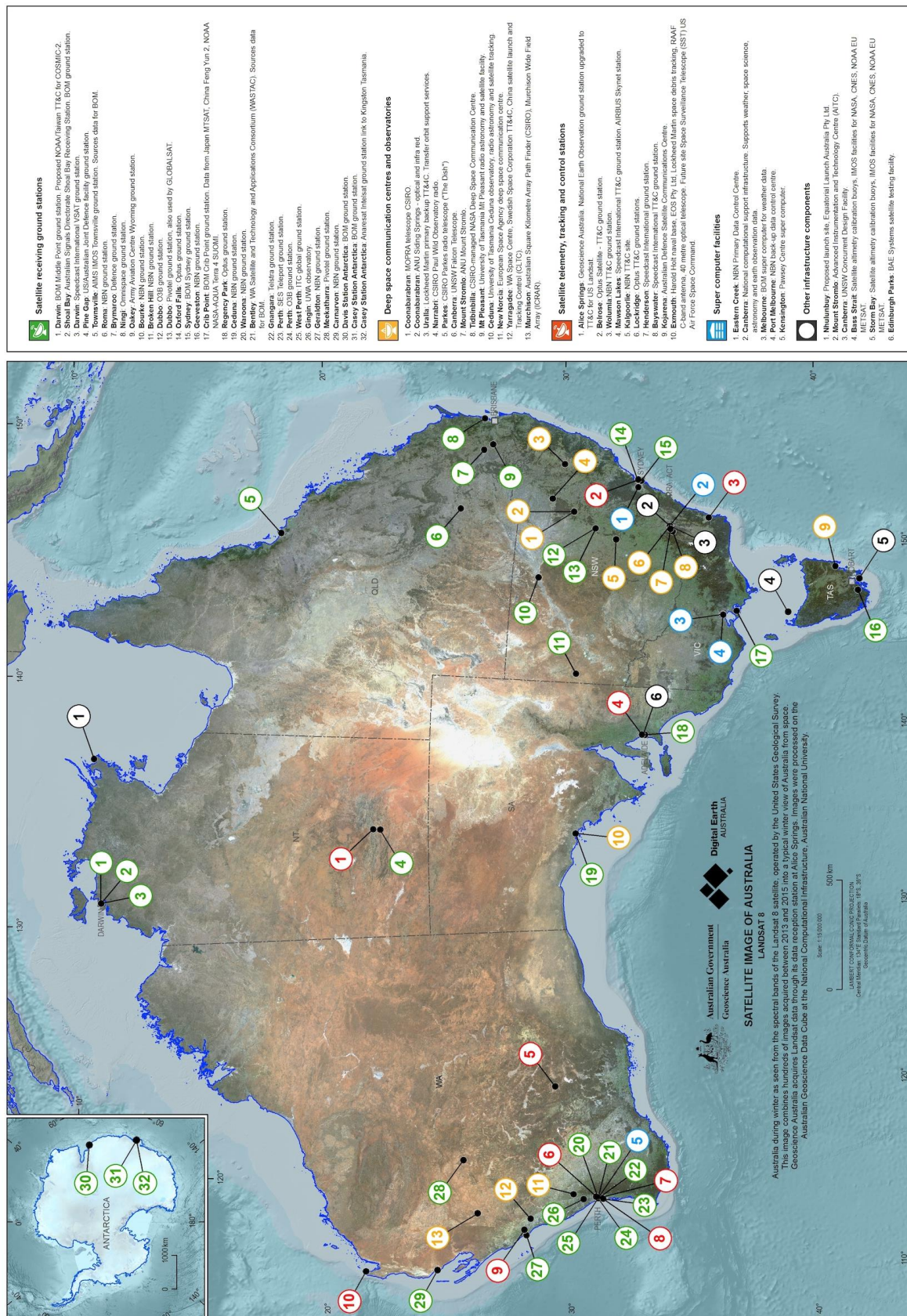


Figure 5: Map of space-related infrastructure ^{F5}

^{F5} Sources: BOM, Geoscience Australia, CSIRO, NBN-CO, Optus, Speedcast International, European Space Agency, Review roundtables, AIMS, University of Tasmania, UWA, ANU, UNSW Canberra.

Chapter 1 – Opportunities for Australia in Space

The Opportunity

Space will be the defining domain of human enterprise in the coming decades. How we use space and the technologies it inspires will play a major role in meeting a wide range of national and international needs and opportunities, from maritime surveillance and ultra-secure communications, to monitoring our natural environment and the resources it provides.

It will remain crucial in our oversight of marine ecosystems and freshwater environments, and in improving emergency management for extreme weather events and bushfires. It will also play a key role in enabling the full potential of future smart cities.



Figure 6: Images depicting some of Australia's challenges and opportunities

Space supports Australia's challenges and opportunities in agriculture, disaster management, communication, environmental management, maritime operations and defence

There are several key arguments for Australia to focus on in regard to capturing a larger share of the global space economy.

The global experience is that space is a reliable growth industry that has proven resilient even in the face of economic downturns. Telecommunications, for example, is the biggest sector in the commercial space market, and has seen consistent and meaningful growth over the past decade, while several satellite operators have been reporting record revenues since 2008, despite the Global Financial Crisis (GFC).³¹

'Northern Territory Department of Environment and Natural Resources and companies such as Maitec Pty Ltd provide bushfire mapping services in the Northern Territory. The satellite-based information they deliver is particularly important in central and northern Australia, where bushfire management information is as crucial for safeguarding productivity as rainfall data.'^{B1}

Space-enabled services also boost productivity to other sectors of the economy, from agriculture and mining to commerce of all types.

However, Australia's industry and Government agencies are entirely dependent on other nations for access to Earth observation (EO) and global navigation satellite systems (GNSS) satellites. Our navigation data is derived primarily from the US GPS constellation, as well as from Russian, European, Indian, Japanese, and Chinese constellations. Australia has a strong reputation for advanced application capability in geospatial positioning, satellite surveillance, Earth observation, and research.

³¹ <https://www.oecd.org/sti/futures/space/48301203.pdf> p. 2

^{B1} <https://denr.nt.gov.au/> and <http://www.maitec.com.au/home.shtml>

Australia is also strong in the area of satellite communications, as well as data downlinks, analytics, and storage, with NBN Co's Sky Muster satellites, Optus' five currently operating satellites, and Speedcast's maritime satellite systems providing land- and sea-based communications services. Notably, all of these satellites were manufactured outside Australia and launched by other nations under contract.

Australia needs to continue to foster these strong partnerships with other space-faring nations to ensure ongoing access and support for operational uses of satellite systems. At the same time, there is now the opportunity to develop a national space capability in niche areas through the direction of the Agency.

Historically, entering the global market has been a challenge, due to the high cost of market entrance. But things have changed, and the divide between Earth and space has not only been bridged – the two have become inextricably linked.

Now, advanced technologies developed in other industries have become a key component of next-generation, low-cost, and agile systems within the space industry, and space technology spin-outs have become a disruptive force in competitive Earth-based industries.

This provides an opportunity for Australia to not only expand our stake in the global space market, but to add real value by facilitating and supporting the development of the local industries that will help us achieve this ambitious goal.

Why Space is Important to Australia

Economic development and the next generation of high-value jobs will become increasingly dependent on digital data and the associated analytics and services. This means space capabilities will be a crucial part of ensuring new high-tech and high-paid jobs are created in the service sector.

In the UK, growth in the industry sector exceeded the average industry growth for more than 13 years up to 2014–2015,³² and this growth has been in both direct space jobs and secondary job generation in the science and services sectors. Total direct employment in the UK space industry increased at a rate of 6 per cent per annum to 38,522 jobs in 2014/15 (0.12 per cent of the total UK workforce), and a total employment supported of 113,866. This equates to just under two spin-out jobs for every space job.³³

'AAM Group recently demonstrated the value of accessing spatial location data that is accurate to within metres, rather than by cruder measures such as postcodes or suburbs, in its new Virtual Sydney 3D model. This innovative program is set to revolutionise the planning, infrastructure, and property development process of Sydney city well into the future.'^{B2}

Continued access to specific satellite-based data for accurate location, Earth observation (EO), maritime surveillance, weather modelling, and emergency management is vital for the Australian economy and makes a tangible difference to the lives of Australians across the country every single day.

For example, EO from space can support economic growth and provide time-based data for planning and monitoring that is both sensitive to environmental considerations and Indigenous history, and can also ensure compliance with regulations.

Access to Japanese, US, and European meteorological satellites provides Australia with regular imagery to support the operations and research of national weather services by the Bureau of Meteorology.³⁴

Space also plays an important role as a source of national inspiration through research, discovery, and exploration, and as a motivating force for young people studying STEM subjects. Maintaining this human

³² UK Space Agency (2016). The Size and Health of the UK Space Industry. <https://www.gov.uk/government/publications/uk-space-industry-size-and-health-report-2016> p. 10

³³ UK Space Agency (2016). The Size and Health of the UK Space Industry. p. 1

^{B2} http://www.aamgroup.com/_blog/News/post/virtual-sydney-set-to-revolutionise-the-infrastructure-and-property-development-of-sydney/

³⁴ http://www.bom.gov.au/australia/satellite/about_satellites.shtml

connection with space and the innovation it inspires will be key to our continued standing as one of the best educated and most entrepreneurial nations on Earth.

Why Australia is Important to Space

Australia's geographic location puts us in a unique position to support satellite communications, Earth observations, and Space Situational Awareness (SSA) for the rest of the world, and Western Australia's vast Murchison region is one of the best sites in the world for radio astronomy.

Our ability to look into the Solar System, combined with our world-class capability in ground station operations, renders us a vital part of communications systems used in global deep space missions.

Australia leads the world in remote asset management, and we have a long history of operating in the hostile, arid, and icy environments of our remote areas and Antarctic regions. This makes our nation a natural partner for space, where technologies developed on Earth can be adapted for space, and space-based technologies can be similarly adapted on Earth.

'Nanometre-level accuracy for satellites was recently achieved by the international Gravity Recovery and Climate Experiment (GRACE) satellite follow-on mission, thanks to prototype hardware developed by the Australian National University (ANU), EOS Space Systems Pty Ltd, the CSIRO, and National Measurement Institute, with NASA's Jet Propulsion Laboratory (JPL) and the German Research Centre for Geosciences (GFZ).'^{B3}

The Australian research community is a global contributor in its research and development (R&D) efforts. Applications waiting to be elevated to the space industry arena include new technology spin-outs in areas such as detector development; materials and structures; thrusters; artificial intelligence; autonomous systems; photonics; secure communications; and quantum technologies.

Within the Earth-observing community, research includes data analysis techniques that convert satellite information to real-world applications related to areas such as urbanisation, infrastructure, agriculture, biodiversity, and indicators of climate change.

The Opportunity to Invest

Major changes in the economics of market entry offer Australia an unprecedented opportunity to invest in space. The need for operational continuity coupled with the ability to develop new types of low-cost satellites has seen governments around the world re-tool to rely more on commercial supply chains. This shift has given rise to competitive new industry players.

Due to a combination of geopolitics, systems reliability, and on-the-ground processing capability, global weather services have traditionally been supported by large, expensive, and highly redundant satellite systems. Recent changes in the global space industry have allowed weather services, led by the US, the UK, and Japan, to explore augmenting traditional data streams with data from commercial suppliers, where volume replaces redundancy on a satellite, and where new analytics methods can better integrate data.

The same agility is also prevalent in low Earth orbit (LEO) observational and communications satellites, which can sustain lower costs to complement the more complex and expensive single-point geostationary satellites.

^{B3} <http://grace.anu.edu.au/about.php>

This dynamic is also increasingly influencing how science missions are operated, with NASA planning to deploy a large mothership with a constellation of small, disposable ‘cube-sats’ to work in tandem on future solar missions.³⁵

How disruptive this change in dynamic will be remains to be seen, but as we’ve witnessed in the computing industry over the past few decades, a complementary mix of large and small systems will likely co-exist in the global space industry.

‘Big picture’ projects such as the colonisation of other planets and the Moon are currently being considered by NASA and other agencies, as well as the private sector, and would provide a unique opportunity for Australia to contribute, based on our expertise in automated mining, food production, novel additive manufacturing, and medical support.

There is opportunity for Australia to focus on major initiatives in this area in partnership with other nations, and this would have long-term implications for both science and discovery.

As with all opportunities, there are also some shorter-term goals. We need to maintain our role in satellite traffic management, and ensure that we facilitate the development of complementary analytical tools and applications.

Having the right strategies and frameworks in place to support the growth of Australia’s space industry sector in the coming decades is essential. However, building an industry that can be Australia-based and deliver on the opportunities ahead of us will be complex.

While there will be excellent opportunities for small- and medium-size enterprises (SME) and research teams to leapfrog the global standard and provide new capabilities, establishing a sustainable business requires a long-term, 10- to 15-year timeframe, with a set of interim goals and achievements.

This is the basis of the Agency’s Strategy and Roadmap, which is discussed in Chapter 2.

Space, Defence, and Security

The continuing expansion of space-based and space-enabled technologies in Australia includes a significant expansion of military space-related capabilities. Worldwide, military forces are increasingly reliant on space-based satellite systems to support networked capabilities, and to communicate and engage when deployed on operations.

As the recent 2017 Foreign Policy White Paper noted, Australia’s growing economic and security interests in space will require robust regulations in order to maximise the benefits of greater access to space, while also addressing challenges such as the accumulation of space debris, which will only intensify in the coming decades.³⁶

At the same time, the expansion of space-based technologies will create risks that we must be prepared to mitigate. Capabilities to disrupt satellites and degrade space-dependent military and commercial systems have the potential to threaten our defence and commercial networks, as well as those of our partners and allies.

In its 2016 Defence White Paper, the Australian Government announced that the Department of Defence would invest in modern space capabilities, and the infrastructure, information, and communications systems that support this vital defence capability.³⁷ Over the next two decades,

³⁵ https://www.nasa.gov/spacetechnology/feature/CubeSat_Missions_Pushing_Boundaries_of_Technology

³⁶ www.fpwwhitepaper.gov.au/foreign-policy-white-paper/ p. 97

³⁷ <http://www.defence.gov.au/WhitePaper/Docs/2016-Defence-White-Paper.pdf>

Defence will invest nearly AU\$10 billion in space-related projects, including the acquisition of major systems, as well as costs associated with project management, sustainment, and personnel.³⁸

Opportunities exist for Australian industry to contribute to these projects across a wide range of areas, including navigation and timing; SSA; intelligence, surveillance, and reconnaissance; communications systems; and R&D.

Within these areas of interest for defence, industries that specialise in construction, installation, integration, in-service support, and provision of major systems or components will be able to carve out a potentially lucrative niche. They will also have the opportunity to contribute components to the global defence space industry, particularly in sub-components such as antennae, power (including solar and power storage), structure, thermal control, command, thrust for on-orbit station keeping, control software, and waveforms used in transmissions.

Space research and development in the defence sector is primarily led by the Defence, Science and Technology (DST) Group, and focuses on new and emerging technologies and the optimisation of existing systems.

Defence policy is to build capability and support industry. The main mechanisms established for Australian industry to contribute to Defence's space projects are the Next Generation Technologies Fund, managed by the DST Group; the Defence Innovation Hub; and the Centre for Defence Industry Collaboration (CDIC).

These mechanisms cover the full spectrum of research partnerships with companies responding to specific requests to supply new technology and solutions.

Australia as a Valued Global Citizen in Space

Australia plays an important role in ensuring safe and secure operations in space, and has the opportunity to be a committed global player in strengthening the international rules and laws that apply to space, including military and commercial uses of extra-terrestrial land.

An important role for the Agency will be to support Australia's commitments under the five United Nations (UN) Space Treaties and lead negotiations regarding bilateral and international civil space and technology safeguards agreements.³⁹

We also have the opportunity to lead efforts in reinforcing and further developing the standards of responsible behaviour in space, alongside our partner states in the UN Committee on the Peaceful Uses of Outer Space.

³⁸ Department of Defence, 2016 Integrated Investment Program, pp 36, 37, 89, 90 <http://www.defence.gov.au/WhitePaper/Docs/2016-Defence-Integrated-Investment-Program.pdf>

³⁹ <http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html>

Chapter 2 – Strategy and Roadmap

Our Vision for Australia's Future in Space

No other industry can inspire nations quite like space, where human ambition can set its sights on interplanetary missions, colonisation beyond Earth, and the possibility of finding new life.

We can dream this big because of the space-based technologies that have connected the world in unprecedented ways, and in the coming decades, our vision is for Australia to become a global leader in pushing Earth's links with space even further.

Major changes in the economics of market entry offer Australia an unprecedented opportunity to invest. Our pathway for Australia is to capture the new opportunities and meet the challenges ahead with a primary goal to enable capabilities that create jobs and contribute new wealth to the Australian economy.

Achieving this requires building a sustainable Australian space industry, underpinned by world-class science and technology; a growing level of capability to design, test, maintain, sustain, enhance and develop space-based technology; and a vibrant ecosystem of globally connected small and mature businesses. We set an ambitious goal for Australia to triple the size of its space industry by 2030 to AU\$10–\$12 billion and increase its share of the global space sector.

Our ambitions extend beyond our national challenges and opportunities. Australia's future in space is as a trusted global partner, playing an important role in ensuring safe and secure operations in space, and strengthening the international laws and regulations that apply to military and commercial uses of space.

Values

Linking our vision, goals, and strategy are the enduring principles and values that relate to *how* Australia will act and not just *what* it will do.

Our values must embrace a commitment to work ethically and with integrity in collaboration with national and global partners; build trust and respect in our interactions; be flexible, creative, and entrepreneurial and reflect the Australian 'can-do' approach.

Australia must be seen as a partner that delivers on its commitments, and as a trusted global partner in the pursuit of safe and secure operations in space.

Our Goal for Australia's Space Industry

Our goal is to triple the size of the Australian space industry from the ERG's estimate of AU\$3.94 billion in the 2015–2016 financial year to AU\$10–\$12 billion by 2030. We aim to provide outstanding job opportunities, including in regional Australia, and to help diversify and grow the Australian economy.

An AU\$10–\$12 billion space industry for Australia by 2030 is an ambitious goal, representing a compound annual growth rate of approximately 8 per cent. This will create an industry that is roughly one-third the size of Australia's current agricultural output of AU\$36.7 billion for the 2015–2016 financial year.⁴⁰ Even assuming a fall in the labour to capital ratio as the sector grows, this would add between 10,000 to 20,000 high-value jobs in the space sector.

⁴⁰ Australian Industry Report 2016, p. 40

<https://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/AustralianIndustryReport/assets/Australian-Industry-Report-2016-Chapter-2.pdf>

A Strategic Framework for the Space Agency

To achieve our vision for Australia and our civil space goals of an AU\$10–12 billion industry by 2030, we provide five key strategic pillars for the Agency, outlined in this and subsequent chapters.

Competitive Advantage: Building on our areas of competitive advantage and leapfrogging into new areas in disrupted market segments. This is further discussed in this chapter.

One Voice, One Door: Setting national policy, strategy, and coordination for the civil space sector, and providing one voice for its ambitions and one door to the world. This includes the role of the Agency in meeting international obligations and commitments for safe and secure operations in space, and strengthening the international rules and laws for space. This will be further discussed in Chapter 3.

International Engagement: Developing an International Engagement Plan, which will identify critical national and international partnerships that are consistent with Australia's objectives both now and in the future. This will be further discussed in Chapter 4.

Grow and Develop: Supporting the growth of a robust and competitive commercial space sector, and addressing gaps in the key industry enablers across the value chain of space, such as R&D capability and training, national infrastructure, capital investment, and facilitative regulation. This will be further discussed in Chapter 5.

Communicate and Inspire: Recognising that Australia's role in space is of utmost importance to the wider Australian economy, and in improving the security, safety, and living standards of all Australians. The Agency will strengthen the connection we all have to space, spark Australia's curiosity and entrepreneurial spirit, and expand our knowledge and interest in space. This will be further discussed in Chapter 3.

Building on Areas of Competitive Advantage

Australia's competitive attributes include high levels of education; strong science and research capabilities; and proximity to other nations with space budgets and business-friendly policies.

Our location in the Southern Hemisphere is advantageous for satellite ground stations, and coupled with our world-class capabilities in ground systems, software, and applications, and close strategic alliances with space powers, particularly in the United States, it puts us in a unique position to expand our role in the global space economy.

We outline below the areas that build on Australia's strengths and utilise national competitive advantage and capabilities:

- communication technologies and services, satellite ground stations and deep space communications network ground stations;
- Space Situational Awareness (SSA) and debris monitoring as part of global networks;
- Positioning, Navigation and Timing (PNT) infrastructure to enhance the competitiveness of the broader economy including agriculture, transport, fisheries, emergency services, mining and oil and gas, and national security;
- the application of advanced integrated Earth observation (EO) satellite data for the benefit of all Australians and the broader economy, and to increase Australian exports of these services;
- space systems that take advantage of the global space technology paradigm shift towards constellations of miniaturised spacecraft for communications and EO;
- research and development (R&D) in areas of national strength to support Australian participation in joint space missions, space tourism, and industry applications, for example, space and remote medicine, space physics, planetary science, astronomy, quantum

communications and technologies, artificial intelligence, and advanced antenna and sensor technology; and

- robotics and autonomous systems for remote asset management on Earth and in space across the broader economy.

1. Communications technologies and services, networked ground stations, and deep space communications network ground stations

Australia can expand its role as a global partner with government and commercial players in communications for human space missions; control, command, and tracking of satellites; and science and discovery beyond our Solar System.

We have an established land and marine satellite communications industry, which gives us the capability to expand in the high-growth sectors of satellite radio, satellite broadband, and fixed satellite services sectors, including uplink and downlink services and internal business networks.

In Australia, wireless mobile coverage now reaches more than 99 per cent of the population, but only around 30 per cent of its landmass.⁴¹ This means geostationary satellites are important for the delivery of radio broadcasting and free-to-air and subscription television services for Australians in remote areas.⁴² Satellite and future space communications platforms will continue to be important if we are to reach all Australians across our vast continent.

In addition to existing communications technologies in the radio spectrum, Australia's clear skies and low levels of cloud cover also provide a unique opportunity to participate in new optical and hybrid optical radio communications.

An important part of building on Australia's existing capabilities in ground system and mission control will be to establish areas where we can secure critical, long-term access to the radio frequency spectrum used by satellite ground stations.⁴³ This must be done while also preserving the highest economic use of the spectrum for public mobile broadband internet and multimedia broadcasting services.

2. Space Situational Awareness (SSA) and debris monitoring

In addition to Australian Defence collaboration with the US in SSA using the C-Band Radar and the planned optical Space Surveillance Telescope (SST) for GEO orbits, Australia has world-class facilities and expertise in SSA that could be used to support commercial activity, and add significant value to the global space economy.

EOS Space System Pty Ltd's laser tracking at ANU's Mt Stromlo Observatory is one example of this, and is supported by RMIT's orbit determination algorithm and adaptive optics expertise at the Advanced Instrumentation Technology Centre (AITC). Another example is the complementary tracking afforded by UNSW Canberra's Falcon telescope, which is part of the growing global Falcon Telescope Network.

Australia's major radio astronomy facilities at Parkes, Narrabri, Coonabarabran, and the Australian Square Kilometre Array (SKA) Pathfinder project and Murchison Wide-field Array in Western Australia have advised the Review that in addition to their primary role in radio astronomy research, they can also provide SSA and debris monitoring capability.

Australia's Desert Fireball Network, operated out of Curtin University, and the collaborative use of the Tidbinbilla and Parkes dishes for asteroid radar with NASA's Jet Propulsion Laboratory (JPL), further strengthen our capabilities.

⁴¹ www.telstra.com.au/coverage-networks/our-coverage and www.optus.com.au/shop/mobile/network/coverage

⁴² Optus confidential submission p. 3

⁴³ ACMA Submission; Geoscience Australia Submission p. 9; Satellite Services Working Group of the Communications Alliance Submission

Australia also has the opportunity to become a key node in the global government networks for both high- and low-precision SSA services for the commercial sector. Such services will secure Australia's position as a trusted global partner, with an important role in ensuring safe and secure operations in space.

3. Positioning, Navigation, and Timing infrastructure

Australia accesses all six GNSS satellite constellations, and as noted by Geoscience Australia,⁴⁴ we are the only developed continent without access to an indigenous, operational, high-integrity, and high-accuracy satellite-based augmentation capability. In addition, our network of global navigation satellite tracking infrastructure that supports high-accuracy positioning is disparate, poorly connected, and not globally competitive.

A high-accuracy satellite-based augmentation system (SBAS) is currently being developed through an industry–Government partnership, which includes Lockheed Martin, Geoscience Australia, GMV Space Systems Inc, and Inmarsat, to provide greater accuracy. This will enable Government and industry to test two new satellite positioning technologies, including next-generation SBAS and Precise Point Positioning (PPP), which will provide positioning accuracies of several decimetres and 10 centimetres, respectively.⁴⁵

Such high-accuracy position location information is a strategic capability for Australia to enable the growth of intelligent transport systems and automation in the broader economy, including transport and logistics, mining, oil and gas, and agriculture.

4. Earth observation (EO) services

EO services is one of the fastest growing segments in the world, with 54 per cent growth between 2011 and 2016.⁴⁶ However, many of our roundtable meetings and submissions noted our lack of sovereign EO satellites. Notwithstanding those concerns, a positive consequence of this is that Australia has acquired a particular competitive advantage in the development of applications that capitalise on all available satellite data, rather than on data from a single set of satellite missions.

'Geoscience Australia's Digital Earth Australia (DEA) translates over 30 years of Earth observation satellite imagery into information and insights about the changing Australian landscape and coastline, providing a ground-breaking approach to organising, analysing, and storing vast quantities of data. It provides access to businesses, researchers, and governments to monitor and track changes over time.'

Such applications provide richer products for end-users, and mitigate the risks of technical failure or data policy changes that come from single-source dependence.⁴⁷

National policy settings and strategy for the space industry should take into account the dependencies of existing operational users of EO services.

These strategies and policies should also recognise the significant opportunities that EO services data, supported by appropriate public and private infrastructure, create for Australian industry. There is a key opportunity for Australia to develop globally exportable products and services enabled with EO services information.

⁴⁴ Geoscience Australia Submission p. 7

⁴⁵ Geoscience Australia Submission p. 7

⁴⁶ Bryce Space and Technology, Global Space Industry Dynamics (2017) p. 6.

⁴⁷ Geoscience Australia Submission p. 3

Investment in digital infrastructure, such as Geoscience Australia's Digital Earth Australia (DEA),⁴⁸ significantly lowers costs and technical risks for new market entrants, including start-ups and SMEs.

5. Research and development strengths: quantum, astronomy, space medicine, and advanced sensors

Australia has world-class R&D capability in several areas, including quantum communications and technologies; astronomy and planetary science; space and remote medicine; and advanced antenna and sensor technology.

Australia's capabilities in quantum communications and technologies⁴⁹ and adaptive optics⁵⁰ are being developed for free space secure communications.⁵¹

Our expertise in optical and radio astronomy has resulted in key roles in global consortia, such as the Giant Magellan Telescope project; collaboration agreements between Australia and the European Southern Observatory; participation by ANU Vice-Chancellor Professor Brian Schmidt in Nobel Prize-winning research into the expanding Universe; and the CSIRO and joint University of Western Australia and Curtin University International Centre for Radio Astronomy Research (ICRAR) hosting the radio astronomy Square Kilometre Array Pathfinder Project (ASKAP), as part of the SKA project.

Since 1993, Australia has advised NASA on human spaceflight for long-duration space missions.⁵² This partnership points to the opportunity for Australian physicians to participate in mission support, and Australian researchers to develop biomedical devices for discovery missions and human tourism.

Our advanced capability in radar and radio antennae, such as the phased array feed technology developed for ASKAP, and CEA Technologies' radar design, development, and manufacture capabilities,⁵³ provide opportunities for the Australian research and industry sectors to participate in joint space missions and global partnerships. This is further strengthened by Australia's capability for world-class design on hyperspectral and thermal sensors.

Australia is globally recognised for its expertise in astronomy, planetary science, and space research. In 2017, we became a strategic partner of the European Southern Observatory (ESO).⁵⁴ This builds on the cooperation agreement established in 2015 between the ESO and ESA.⁵⁵

Investment in ESA science discovery missions has shown a return of between 7:1 and 12:1 from technology transfer on average across the various member states.⁵⁶ This is particularly true of planetary missions, such as the UK Beagle 2 mission's gas analysis package, which received funding from the Wellcome Trust for technology transfer in medical applications. Science discovery missions also serve as a vehicle to capture public imagination and enhance the reputation of a nation.

The numerous international relationships and existing agreements between Australia's astronomy, planetary science and space research communities, and agencies such as NASA, DLR, CNES, JAXA, and the ESA can be leveraged to fast-track Australia's space industry development, and highlight our technological capabilities on the world stage.

⁴⁸ <http://www.ga.gov.au/about/projects/geographic/digital-earth-australia>

⁴⁹ [dpir.nt.gov.au](http://www.dpir.nt.gov.au)

⁴⁹ <http://www.cqc2t.org>; <http://photonics.anu.edu.au/qoptics/index.php>; <https://www.quintessencelabs.com/>

⁵⁰ <http://rsaa.anu.edu.au/aitc/adaptive-optics>

⁵¹ <http://www.marketwired.com/press-release/quintessencelabs-326-million-investment-from-australian-department-defence-quantum-key-2226428.htm>

⁵² Lugg DJ, Shepanek M. 'Space analogue studies in Antarctica.' *Acta Astronautica* 1999; 44: p. 694.

⁵³ www.cea.com.au

⁵⁴ <https://www.eso.org/public/news/eso1721/>

⁵⁵ <https://www.eso.org/public/images/ann15064c/>

⁵⁶ European Space Agency, Final Report on the Space Economy 2016, p. 84.

6. Space and remote Australia as natural partners

Australia leads the world in remote asset management, with autonomous trucks at iron ore mines in Western Australia being controlled remotely, 24 hours a day, 365 days a year, from thousands of kilometres away. The same region is also expected to become host to the largest robot on Earth; a fully automated ore train, and automated drills later in 2018.⁵⁷

‘Rehabilitation of legacy mines has become a key issue in the Northern Territory, with an estimated unfunded liability of more than AU\$1 billion. The Legacy Mines Unit^{B4} has installed equipment connected to satellite and broadband telemetry at hard-to-reach locations to remotely monitor conditions such as rainfall, humidity, and temperature.’^{B4}

Woodside Australia, which has an existing partnership with NASA,⁵⁸ is using artificial intelligence, advanced analytics, and 3D-printed parts for the remote maintenance of its offshore rigs. Dairy farms in Tasmania are partnering with Fleet Space Technologies to inform strategic decisions through the use of space-based data from sensors connected to a nanosatellite network.

Australia also has a long history of advising NASA on human spaceflight through its Antarctica Analogue Studies,⁵⁹ as the harsh environment of the most hostile continent on Earth allows NASA scientists and engineers to develop equipment and safety protocols for long-duration space missions.

⁵⁷ <http://www.riotinto.com/australia/pilbara/mine-of-the-future-9603.aspx>

^{B4} Claire George, Northern Territory Department of Trade, Business and Innovation pers.comm.

⁵⁸ [http://www.woodside.com.au/Investors-](http://www.woodside.com.au/Investors-Media/announcements/Documents/02.02.2017%20NASA%20Robonaut%20to%20touch%20down%20at%20Woodside.pdf)

[Media/announcements/Documents/02.02.2017%20NASA%20Robonaut%20to%20touch%20down%20at%20Woodside.pdf](http://www.woodside.com.au/Investors-Media/announcements/Documents/02.02.2017%20NASA%20Robonaut%20to%20touch%20down%20at%20Woodside.pdf)

⁵⁹ <https://www.nasa.gov/hrp/research/analog/antarctica>

Leapfrogging in Areas of Disruptive Technology

The global space sector is undergoing a major paradigm shift, as satellite miniaturisation has enabled the production of highly capable devices to meet key terrestrial needs at a vastly reduced cost, and with a much shorter innovation cycle.

At the same time, other sectors such as genetic research and information technology are undergoing disruption through the introduction of new technologies and innovative business models.

Australia has strengths in many of these disruptive technologies, such as quantum computing, autonomous systems, and artificial intelligence. Priority should be given to the process of selection, R&D funding, and commercialisation of the niche 'swim lanes' where Australia can combine space capability with disruptive technologies from other sectors, and leapfrog into world leadership roles and a significant market share.

Australia is positioned to take advantage of the paradigm shift towards constellations of miniaturised spacecraft for communications and Earth observations. Through university and industry participation by companies such as Myriota, Fleet Space Technologies, and Skykraft, the Australian space sector has been actively growing its miniaturised satellite capacity and capability.

Examples of such projects in the university sector include the international QB50 cube-sat mission by the University of Sydney, UNSW, the University of Adelaide, the University of South Australia, and ANU; and the development of UNSW Canberra Space and its joint Buccaneer cube-sat program with the DST Group, and three cube-sats for the Royal Australian Air Force (RAAF).

While ongoing strategic assessment is needed to give us a true picture of the potential opportunities, we highlight the following frontier areas where Australia can lead and bolster the broader economy:

- the application of artificial intelligence, robotics, and big data analytics to space systems and space-derived information;
- the application of next-generation communication technologies, including optical and hybrid optical radio;
- quantum communications to enable secure, broadband space-based communications;
- innovative sensors, antennae and instrumentation;
- constellations of miniaturised spacecraft for communications, Earth observation, and the Internet of Things (IoT), which will use these constellations to connect to sensors and devices around the world; and
- next-generation rocket and spacecraft propulsion systems.

The Roadmap

Building an Australian-based industry that can deliver on key opportunities will take time, and will not be easy. There will be some 'quick wins', and the small business and R&D community will see success by leapfrogging in key areas to provide new and innovative capabilities, but building a sustainable business requires a long-term, 10- to 15-year roadmap with a set of interim goals and achievements.

It also requires a sense of the size of the Agency's budget that would allow Australia to reach its goals and win a larger share in the global space market.

Comparisons with the commercially focused space agencies of the UK, Canada, France, and Norway indicate that nations investing in space to grow and diversify their economies are investing between 0.016 per cent and 0.07 per cent of GDP in space agency funding (Figure 7).⁶⁰

Raising Australia's investment over time to come within the lower end of this range would mean a budget in the order of AU\$250 million per annum, with the capacity to fund specific, time-bound missions of national importance, such as Canada's private–public partnership in the Radarsat satellites,⁶¹ and the UK's recently announced £90 million investment in a shared national facility for satellite testing at Harwell.⁶²

Australia will need to set its priorities wisely to ensure that there is a focus on areas of investment that will build industry capability over time.

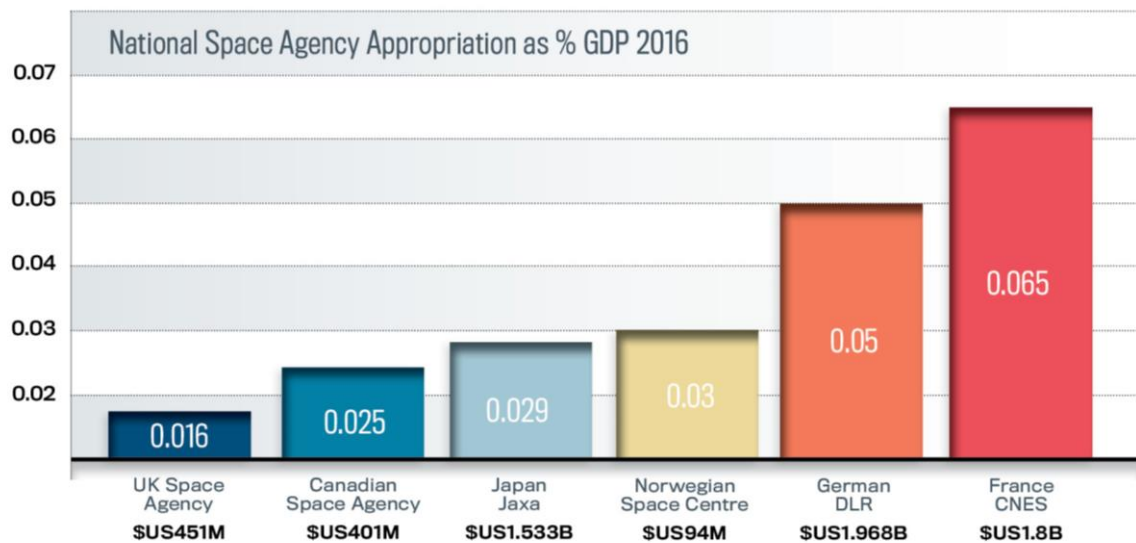


Figure 7: National space agency annual appropriation as a percentage of GDP in 2016⁵⁷

⁶⁰ UK Space Agency Corporate Plan 2017–18. CNES Annual Report, 2016; Canadian Space Agency Financial Statements 2016–2017; Norsk Romsenter 2018. Figures include government appropriations and are compared on a Purchasing Power Parity basis (Source: OECD. 2018. OECD.Stat, PPPs and Exchange Rates. Note: Figures for the German Agency DLR are for 2015)

⁶¹ <http://www.asc-csa.gc.ca/eng/satellites/radarsat2/Default.asp>

⁶² <https://www.gov.uk/government/news/100m-boost-for-uk-space-sector-to-ensure-uk-is-equipped-to-stay-ahead-of-the-competition>

Table 2: Unique roles, strategic framework, and staged funding pathway for the Agency

ROLE	2018 - 2019	2019 - 2021	2022 - 2028
National-scale projects and missions		Options for national scale projects	Regular national-scale projects funded. World-class SME development Upstream, downstream technology and ground-based capability to leapfrog Australia into areas of world leadership International engagement to 0.016% of GDP
Facilitating industry growth	Seed initiatives from core funding	SMEs in global supply chains and industries of scale developing	SMEs in global supply chains and industries of scale developing Space Industry Development Fund World-class State and Territory nodes Industry development in strategic and leapfrog areas
Communication, trusted advisor, skills and training	Engagement and Inspiration Skills gap analysis	Space Industry Development Fund	Trusted advisor Engagement and inspiration STEM and skills gaps initiatives
"Front door"-international and national engagement International obligations	Extend existing partnerships Establish new partnerships	World-class State and Territory nodes	Leadership for safe, secure operation Industry access to multiple technology and product development partnerships Extend existing and new partnerships
National policy and strategy	Agency Charter, National Policy and Strategy to 2030	Industry development in strategic and leapfrog areas	National Policy and Strategy Industry and economy impact metrics Whole-of-government national coordination

AGENCY ROLE AND ANNUAL BUDGET RAMP-UP

\$25M pa \$50M pa \$100 - \$250M pa

Strategic Coordination, Governance, and Investment

The governance and resources to support the Agency strategy will be discussed in Chapter 3.

Recommendations

Recommendation 1:

The Agency is responsible for the development of a national space industry strategy, and that strategy gives priority to areas that build on Australia's strengths and utilises national competitive advantage and capabilities, in particular:

- communication technologies and services, satellite ground stations, and deep space communications network ground stations;
- Space Situational Awareness (SSA) and debris monitoring as part of global networks;
- Positioning, Navigation, and Timing (PNT) infrastructure to enhance the competitiveness of the broader economy including agriculture, transport, fisheries, emergency services, mining and oil and gas, and national security;
- the application of advanced integrated Earth observation (EO) satellite data for the benefit of all Australians and the broader economy, and to increase Australian exports of these services;
- research and development in areas of national strength to support Australian participation in joint space missions, space tourism, and industry applications, for example, space and remote medicine, space physics, planetary science, astronomy, quantum communications and technologies, artificial intelligence, advanced antenna and sensor technology; and
- robotics and autonomous systems for remote asset management on Earth and in space across the broader economy.

Recommendation 2:

The national space industry strategy gives importance to emerging frontiers where Australia can leapfrog into areas of future competitive advantage, including the application of artificial intelligence, robotics, and big data analytics to space systems and space-derived information; next-generation communication technologies, including optical, hybrid optical radio, and quantum communications, to enable secure, broadband space-based communications; innovative sensors, antennae, and instrumentation. Australia should also take advantage of the global space technology paradigm shift towards constellations of miniaturised spacecraft for communications and Earth observations, and next-generation rocket and spacecraft propulsion systems.

Chapter 3 – The Australian Space Agency

Now is the right time for Australia to capitalise on our unique geographical advantages, world-leading expertise, and tireless ambition, and expand our reach as a global player in the new space economy.

Guided by the strategy laid out in this Report, we have the capacity to grow the size of the Australian space industry from the Expert Reference Group's (ERG) estimate of AU\$3.94 billion for the 2015–2016 financial year to AU\$10–\$12 billion by 2030, making it a key contributor to the growth and diversification of the Australian economy. Growth of our space industry will provide an initial additional 10,000 high-level jobs in our cities and regions, while creating a sustainable and important capability for Australia from a defence and commercial perspective. Space is integral to how we communicate, locate, and see the world. In fact, space provides the capabilities we all rely on every day as we live, chat and move through life – imagine life without email, mobiles or GPS! Space underpins the ability of Australia's key sectors such as agriculture, maritime, gas, mining and transport to remain world-leading. A vibrant space industry will provide greater certainty and future-proofing for Australian business and our economy. A dedicated Australian space industry will also change how we live and work in remote and regional Australia, including providing new opportunities for communication in our regional areas.

The fundamental enablers of this strategy will be the governance arrangements for the Agency, which will facilitate national coordination and grant access to the resources required for its objectives and roadmap.

We outline below the roles and responsibilities, structure and governance of the Agency as outlined further in the agency charter in Appendix 6.

Purpose of the Agency

The purpose of the Agency is to fulfil the vision outlined in Chapter 2 and to deliver of goal of tripling the size of space industry by 2030. The Agency's key roles and responsibilities are to:

- lift national and international engagement
- set national policy and strategy to realise Australia's ambitions in the civil space sector
- facilitate growth in space industry sector
- inspire the nation with Australian's contribution to human endeavours in space

Roles and Responsibilities

A single voice for national policy, strategy, and whole-of-government coordination

Almost all of the submissions to the Review (Appendix 2) emphasised the importance of an Australian space agency taking the lead on national policy and strategy coordination, and called for a single voice to coordinate whole-of-government and inter-governmental policy for Australian civil space sector activities and ambitions.

The importance of the Agency as a whole-of-government entity is both for the purposes of providing a strategic focus to space-related activities and to guide the civil space-related investment choices of the Australian Government.

It is important that the Agency utilise and support an ecosystem of active space players in Australia across Government, industry, and academia. The aim is not to absorb ongoing work, but to add value and bring additional benefit to the work undertaken across the country.

The Agency will need to ensure that the national strategy for civil space has appropriate alignment to national defence, security, and communication policy. It is recognised that while the Agency is not responsible for national defence and security policy, a strong national space industry sector is important for the reinforcement of these areas.

National security will continue to be managed by the Department of Defence, and communications policy and spectrum allocation will be managed by the Department of Communications and the Arts. The role of the Agency will be to bring strategic focus to the entire suite of activities, not overtake the functions that are being effectively carried out by Government departments that relate to space.

The Department of Defence has given policy priority to increasing the coordination between industry and defence capability requirements. Its key initiatives under this policy are the Next Generation Technologies Fund, managed by the Defence Science and Technology (DST) Group, and the Defence Innovation Hub. It is also committed to establishing the Centre for Defence Industry Collaboration (CDIC), with the goal of placing individual hubs in each State.

We see these activities as good models that the Agency can use to build industry capability and collaboration in the space sector.

To provide certainty for industry, minimise regulatory burdens, and assist growth of the industry, the Agency should be responsible for regulating Australian space activities under the *Space Activities Act 1998* or any replacement and/or amended legislation, and aligning the national regulatory framework for space-related activities as far as possible with other relevant legislative frameworks, including with respect to launch certificates.⁶³

International engagement and support for critical partnerships

A key role for the Agency will be to support Australia's international commitments. This includes upholding our responsibilities as a party to the five UN Space Treaties, and leading negotiations regarding bilateral and international Space and Technology Safeguards Agreements.

Alongside our partners, Australia will lead efforts to strengthen the standards of responsible behaviour, particularly through the United Nations Committee on the Peaceful Uses of Outer Space.

The Agency will also ensure that Australia's interests are represented at international forums on space and space-related activities to give us the singular voice we need to strengthen our standing in the global space economy.

It's important to note that Australia has interests and international obligations with regards to arms controls, and space activities may also be subject to export control requirements, whether undertaken by Government, industry, or academia.

As evidenced by the submissions and at State and Territory roundtable discussions, researchers and industry players across Australia feel that a space agency could facilitate the strengthening of critical partnership agreements and the building of new partnerships.

Due to the relative size of the Australian space industry, we cannot do this alone, which means effective and stable partnerships will play a crucial role in ensuring that we achieve our goals. Our capacity to add value to these partnerships has been demonstrated through our decades-long history as an important and reliable partner in the global space economy.

⁶³ <https://www.legislation.gov.au/Details/C2004C01013>

In 1969, Australia supported the US through the first Moon landing, allowing the world to watch it live on television via the Honeysuckle Creek Tracking Station near Canberra. Our treaty-supported partnership with NASA ensured that one of the three deep space communication centres on Earth is in Australia, and we became the prime receiving station for the Mars landing of the Curiosity rover in 2012. Australia will also be a critical node in all planned missions of NASA and the European Space Agency in the coming decades.

As further outlined in Chapter 4, Australia is uniquely qualified to offer ground location support to our international partners, with world-leading capabilities in applying integrated Earth observation data to planning, production, and environmental monitoring. Through our development of advanced on-board technologies and communications equipment, our expertise will ensure the safeguarding of operations in future space endeavours.

To ensure that our partnerships remain successful, Australia needs to have a single voice within the international space sector, facilitated by the Agency. This will also allow us to develop new partnerships with government space agencies and commercial partners.

The Agency's role and responsibilities will include developing an International Engagement Plan, which will identify critical national and international partnerships that are consistent with Australia's current and future objectives.

During our consultations, the issue of European Space Agency (ESA) membership was raised. This remains an open issue, and relationships with the ESA should be determined by the Agency as part of its first implementation plan.

The Agency's role in regional and international engagement will be further discussed in Chapter 4.

State and Federal cooperation

The execution of a strategy to take Australia's civil space capability to the world stage is a national endeavour requiring cooperation between Federal, State and Territory Governments, Government agencies, academia, and industry. State and Territory Governments set policy and strategies to diversify their economies, grow the jobs of the future, and make best use of their land and marine assets.

The Agency should have a role in both supporting new State and Territory civil initiatives in space, as well as ensuring States and Territories within the national space community have appropriately integrated strategies that are aligned with the national strategy and plans, such as the industry-recommended National Capability Plan and International Engagement Plan.

Australia's capabilities are spread across different States, with various clusters of expertise.

South Australia hosts a vibrant community of small, start-up, and established Australian companies, and has strong links with the defence industry. In September 2017, the South Australian Government created the South Australian Space Industry Centre to support space entrepreneurs; create an incubator for space projects; and build an environment where new space technologies can be developed at an accelerated timeframe.⁶⁴ It will provide grants of up to AU\$1 million each year to young space entrepreneurs and new and existing space start-ups through its Space Innovation Fund.

Western Australia hosts major space commercial, defence, and research ground stations;⁶⁵ international radio astronomy collaborations; and the Pawsey Supercomputer for space-related data. It hosts

⁶⁴ https://www.sasic.sa.gov.au/docs/default-source/default-document-library/media-releases-2017/sa's-giant-nation-leading-leap-into-space-industry.pdf?sfvrsn=8e8f5217_2

⁶⁵ See Figure 5

partnerships that are developing robotics for use in space and in industry management of remote assets, and global companies such as AAM Group. It also has key ground stations for the ASX-listed, Hong Kong-based Speedcast International.

The ACT hosts the CSIRO-operated NASA Deep Space Communication Centre; the CRC for Space Environment Management at the ANU's Mount Stromlo Observatory; world-class research such as DST Group-UNSW Canberra Buccaneer satellite program and RAAF satellites and UNSW-RAAF satellite program; and leading space companies including EOS Space Systems Pty Ltd, Geospatial Intelligence, Geoplex, and Quintessence. The ACT signed a memorandum of understanding with South Australia on 21 August 2017 to further develop their space industries.⁶⁶ The ACT and South Australia have both developed and released space capability directories in 2017 and 2016, respectively.

The Northern Territory hosts ground stations for commercial land and marine communications, Defence, and the Bureau of Meteorology and Geoscience Australia. The Northern Territory Government has strong Earth observation (EO) capability, undertaking world-leading rangeland mapping, fire monitoring, and grass mapping using data from the Landsat and Sentinel satellites. Speedcast International operates the V-Sat ground station used by Government and marine communications network, School of the Air, and also delivers the Australian Border Force Wideband Management Systems for satellite communications to the Cape Class Patrol Boats⁶⁷.

Tasmania hosts the Integrated Marine Observation System (IMOS) sea-level calibration buoys and a commercial ground station for NBN Co. The University of Tasmania's Radio Astronomy and Satellite Facility at Mt Pleasant is used for commercial de-orbit tracking. Tasmania also hosts a strong space medicine node using experience from Antarctica. The Australian Government's Australian Antarctic Division based in Tasmania hosts the Anasat/Intelsat ground station, which links the Casey Station in Antarctica to Kingston in Hobart.

Queensland is host to the Boeing research and development centre, established with University of Queensland in July 2017, where Boeing worked with Opaque Space to develop a virtual reality simulator for training astronauts to operate the CST-100 Starliner and dock with the International Space Station.⁶⁸ The University of Queensland also hosts hypersonics and scramjet research, and the State has deep capability in Earth observation analytics, with companies such as Ozius Pty Ltd, Geoimage, and GIS People, as well as ground and marine equipment manufacturing.

Victoria hosts the Bureau of Meteorology Crib Point Satellite Earth Station and supercomputer, as well as the NBN Co back-up data control centre. It has ground equipment manufacturers and suppliers such as GPSAT Systems Australia Pty Ltd, Satplus Australia, and Skybridge Group Pty Ltd.

NSW is host to satellite communications operators and service providers, such as Optus Satellite Pty Ltd, NBN Co, Telstra, and Pivotal Satellite. It hosts global positioning company, Position Systems Pty Ltd, as well as having a significant number of the nation's small and start-up businesses.

The NSW-based ARC Training Centre for CubeSats, UAVs, and Their Applications is a AU\$4.6 million, five-year program committed to training the next generation of professionals in advanced manufacturing, entrepreneurship, and commercial space and unmanned aerial vehicle (UAV) applications. It also aims to develop new instruments, technology, and products to solve crucial problems, and develop a world-

⁶⁶ <https://www.premier.sa.gov.au/index.php/jay-weatherill-news-releases/7921-joint-effort-by-sa-and-act-to-launch-national-space-agency>

⁶⁷ <https://www.speedcast.com/australian-border-force-chooses-speedcast-to-deliver-a-wideband-management-system-for-satellite-network/>

⁶⁸ <https://www.uq.edu.au/news/article/2017/06/boeing-opens-research-centre-uq>

class Australian industry in cube-sats, UAVs, and related products.⁶⁹ The Training Centre received funding not only from the ARC Industrial Transformation Training Centre (ITTC) scheme, but also from Australian space SMEs, Australian and international universities, and Australian Government departments.

An important role for the Agency is to support national activities in partnership with State and Territory Governments and industry to facilitate growth of Australia's space economy, research capability, and design and test facilities. The Department of Defence's model of Centres of Industry Defence Collaboration (CIDC) provides a good example of how hubs for the Agency can be established to support States and Territories.

It is imperative that the Agency works with the States and Territories to develop areas of capability and combine with State-based resources to ensure that these hubs contribute effectively to the national goals and strategies.

Formal governance mechanisms for coordination with the States and Territories will include the Agency Head establishing a Space Industry Leaders Group and a National Space Advisory Forum.

Activities and support for industry growth and development

An important sentiment that ran through all of our consultations is that Australia has the opportunity to greatly expand its role in the global space economy, facilitated by an integrated approach to policy and strategy on space. Specifically, the Review determined that a long-term plan for Australia's space industry is needed to support the innovative application of space technologies, and grow Australia's domestic space industry.

The Agency will have prime responsibility for developing and leading the national policy and strategy to further grow the Australian space industry sector. It will also play a role in further diversifying and expanding the broader Australian economy.

In fulfilling this role, we recommend that the Agency consults with the heads of relevant agencies, departments, State and Territory Governments, industry, the science and research community, and other relevant stakeholders, as it develops national policy and strategy.

An important first step will be for the Agency to develop and implement a National Space Industry Capability Plan that identifies existing opportunities for Australia. It will also identify new and emerging areas where Australia could become a world leader, and ensure that the interests of Australian businesses remain at the forefront of Government policy directed towards space-related activities.

The National Space Industry Capability Plan will ensure that Australia develops and retains strategic capability in space. This will include the capability to design, test, maintain, sustain, enhance, and develop space-based technologies, ground assets, science, and appropriate space-related applications. It will encourage further collaboration involving industry and research, and include a roadmap to develop capability over time.

A critical part of building national capability, confidence, and collaboration with research and industry will be to undertake mission-scale projects. The Agency's responsibilities should include developing and proposing capital investment every three to four years in major space missions. These would include national satellite projects, Earth observation missions, and discovery science missions.

⁶⁹ <https://rms.arc.gov.au/RMS/Report/Download/Report/a3f6be6e-33f7-4fb5-98a6-7526aaa184cf/180>

An effective evidence base for Australia's space industry

In order to set national policy and strategy, and to guide Government investment in space-related programs, an effective evidence base is required.

The Agency will be responsible for biennial reporting on the capability of Australia's space industry, and for providing an annual report to Parliament on Australia's space sector, including evidence for assessing progress against the performance measures set out in the national policy and strategy.

The report should subsume the existing annual State of Space Report produced by the Department of Industry, Innovation and Science.

On a State level, the Space Capability Directories developed by the South Australian Government are an impressive showcase of the South Australian space industry, and we recommend that the Agency foster efforts in other States and Territories to produce such reports. These would be consolidated every two years by the Agency into a National Space Sector Directory.

Research and development

Australia has a vibrant R&D base in the space sector (Appendix 4) and this is a critical component in achieving our vision. We are not recommending that the Agency be a research body itself, as that role is being effectively undertaken by the university sector and the Government Agencies of the CSIRO, Geoscience Australia, the Bureau of Meteorology, and the Defence Science and Technology (DST) Group.

It is critical that the Agency establishes an ecosystem for these research activities and their links to the industry and State activities that can thrive without formally being inside the Agency.

We note the importance of the Agency in working to develop and strengthen collaboration between the space industry and research sector, especially in areas where Australia is looking to build on existing advantages, and those where we are looking to leapfrog through innovation. The Agency will leverage and influence where research funding is directed to support the strategic objectives of expanding the space sector for maximum national advantage.

Inspiring the next generation

Across the country, the Review has been inspired by the creativity, entrepreneurship, and sense of discovery in the Australian people. Our track record in space and the many achievements of Australians at home and abroad only emphasise the urgency with which we should be pursuing a consolidated place on the world stage.

A vital part of the Agency's objectives will be to effectively communicate to the Australian people our expanding role in space, and its importance to the nation's economy, security, safety, and living standards of all Australians. This includes supporting efforts that strengthen the connection that young people and their parents have with space, sparking their curiosity and entrepreneurial spirit, and expanding their knowledge and interest in STEM subjects.

The Agency should further assist in the development of the next generation of Australian space professionals by promoting space education and space-related projects within the community; supporting the jobs of the future in space-related sectors; and supporting the use of space technology in the broader economy.

The Agency will also be responsible for completing a skills and training gap assessment and ensuring that the relevant Government department policies and strategies address these in an appropriate timeframe.

Governance and Structure of the Agency

Continuity, clout, and resourcing are the key to fulfilling Australia's ambitions in space. To ensure that the Agency is equipped to establish itself as a highly effective representative of Australia's contributions and expertise on the world stage, we recommend that it be a whole-of-government entity.

The Agency will also require the appropriate expertise to advise on the nation's investment in civil space activities, and to support Australia's international obligations and partnerships.

Establishing the Agency as a whole-of-government statutory entity will be important to realise Australia's civil ambitions in space, as well as provide important coordination across Government. Recognising that it will take time to put statutory arrangements in place, we have recommended interim arrangements.

The Head of the Agency should be appointed by the Minister with portfolio responsibility for civil space activities, and be supported by a Steering Board responsible for oversight and advice to the Minister on appointment of agency head and the strategy, governance, and performance of the Agency. The Board will meet at least quarterly and should include appropriately skills and industry experience.

To support the Agency's role as a whole-of-government entity, we recommend that the Head of the Agency report twice yearly to the relevant sub-committee of Cabinet. The Agency Head will also establish a Space Industry Leaders Group and a National Space Community Advisory Forum to support coordination with industry and the States and Territories.

We recommend that interim arrangements are established immediately on the basis that the Agency becomes a statutory agency as soon as is practical.

Recommendation 3:

The Government establish a dedicated, ongoing, and whole-of-government statutory agency (the Agency) to realise Australia's civil ambitions in space, and that interim arrangements are made to establish the Agency immediately. The Agency will be responsible for civil strategic policy direction setting, international representation, coordination of national civilian activities, and strategies to facilitate the growth of the Australian space industry sector as set out under the Agency Charter.

Recommendation 4:

The Government provides ongoing, core operational funding to the Agency to enable its establishment and effective operation with additional funding for an ongoing Space Industry Development Fund once the Agency is fully operational. This Fund will invest in: international partnerships to enable increased industry participation; industry-led collaborative research and development in the areas of strategic priority and leapfrog technologies; and support for national nodes in partnership with State and Territory governments and their industries. It will also provide early stimulus to national infrastructure such as enabling commercial ground stations and shared test facilities for satellite manufacture and equipment verification.

The Government provides scope for the Agency to bring forward for dedicated funding every three to four years, major national space projects such as satellite projects, to meet national and international terrestrial and marine needs, and to participate in discovery science missions as part of international consortia and national space competition missions.

Chapter 4 – International Engagement

Australia's partnerships in the global space economy are vital. Together with our world-class facilities, leading expertise, and unique geographic location, these strong international relationships will help us achieve great things in the years to come.

As discussed in Chapter 3, establishing and developing public sector and industry partnerships, both regionally and internationally, will be a crucial part of ensuring continued innovation and investment in Australia's space industry.

The Agency will establish a common view and approach to Australia's future endeavours in the space industry, and communicate that to the regional, global, research, Government, and industry sectors with a single voice.

Valued Partners on the World Stage

Australia's track record as a partner in the space economy provides a foundation upon which to strengthen existing partnerships and forge new ones in our region. We also have the opportunity to position ourselves as the preferred global partner for new commercial entrants in the space economy.

Australia's ability to provide leading ground station facilities for satellites allows us to support existing ground stations and deep space communications centres, while also developing partnerships that will help us establish vital new ground links with space.

We are also leading the world in our capacity to integrate Earth observation (EO) data with other on-ground data. This is evidenced by Geoscience Australia's open-source Digital Earth Australia, which is being implemented in the US, Columbia, Kenya, the UK, Vietnam, and Switzerland; and AAM Group's base model for 3D city maps, which has been implemented in Sydney, Brisbane, Singapore, Hong Kong, South Africa, and New Zealand.

'Australia's Integrated Marine Observation System (IMOS) partnership operates one of four global sites supporting high-precision satellite altimeter missions to measure sea level variations with unparalleled accuracy. These missions inform our understanding of how the oceans affect Earth's climate system by allowing us to measure sea level variations at global and regional scales.'

Our capability to provide vital on-board technology for satellites and spacecraft missions is exemplified by the hyperspectral scanner developed by La Trobe University in Melbourne for the German Space Administration (DLR), and the long-term collaboration between NASA and the Australian Antarctic Division.

Our reliability as a partner has meant that we are a vital node in international weather services, space weather, and ocean measurement. Australia also assists in the calibration and validation of satellite measurement tools to support the mission agencies of NASA; the French Space Agency, CNES; the US National Oceanic and Atmospheric Administration (NOAA); and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) via the Ocean Surface Topography Science Team (OSTST).

Building on Existing Partnerships

From the very beginnings of human endeavours in space, Australia has fostered strong international partnerships with space-faring nations. For decades, this has enabled us to play key roles in major exploratory missions.

From the first steps on the Moon to the end of Cassini's mission to Saturn, we've been right there with our US partners as a prime tracking and communications services provider.

Our partnership in space missions was formalised in 1960 with a bilateral treaty on space vehicle tracking, and within two years, the CSIRO Parkes Radio Telescope was being used to receive signals from NASA's Mariner 2 spacecraft. An agreement to continue this partnership between the US and Australia was concluded in October 2017. This new Space Tracking Treaty names NASA and the CSIRO as the respective implementing partners of the two countries to the treaty.⁷⁰

This agreement enables the CSIRO to continue operations of the Australian node of the NASA Deep Space Network in Canberra, where it has been monitoring spacecraft across the Solar System for more than 50 years. The CSIRO provides Southern Hemisphere contact with more than 30 spacecraft, which have been included in missions to Mars, Venus, Jupiter, Pluto, the Moon, the Sun, and beyond the Solar System.

The treaty also provides for CSIRO involvement in Tracking and Data Relay Satellite equipment sites in Alice Springs and Dongara, which support communications with the International Space Station.

Under separate bilateral agreements, the CSIRO manages NASA's scientific ballooning station in Alice Springs, which has recently been used by Japan and France to send high-altitude atmospheric and space observatories aloft.⁷¹

Geoscience Australia has had a long partnership with the US Geological Survey for the operation of the Alice Springs ground station, which has been receiving Landsat data since 1977, and is now one of the three stations used globally for controlling Landsat satellites.

In 2016 Australia signed agreements with the European Commission and European Space Agency (ESA) to enable the delivery of European Copernicus data, and ESA EO Science data to the Australasian region. This agreement and the subsequent development of the Copernicus Australia regional hub has so far seen over 1 petabyte of free and open satellite data made available to all Australians.⁷²

Australia's partnership with the ESA is also strengthening, with plans for the expansion of the ESA's Deep Space Communication Centre in New Norcia to support planned Solar System missions. ANU has also formed a partnership with the DLR in quantum technologies for secure optical communications and space-based infrared sensor packages.

More widely, the Australian astronomy and planetary research community has teamed up to access data from international astronomy missions such as Hubble, Planck, Herschel, and NASA's Wide Infrared Survey Explorer (WISE).

Australia will need to ensure participation in key multilateral forums, some of which are shown in Table 3 below, to maintain a single front door to the world and continued access to free and open space-based data for industry and Government. These data will in turn provide important services for industry and the wider Australian community.

⁷⁰ <http://minister.industry.gov.au/ministers/sinodinos/media-releases/australia-and-united-states-sign-historic-space-treaty>

⁷¹ ACIL ALLEN Australian Space Industry Capability 2017, p. 4

⁷² <http://www.copernicus.gov.au>

Table 3: Key multilateral partnerships for Australia

Organisation/Group	Organisation/Group Cont.
Intergovernmental Group on Earth Observations (GEO)	Committee on Space Research (COSPAR)
Committee on Earth Observing Satellites (CEOS)	International Astronomical Union (IAU)
UN Committee on the Peaceful Uses of Outer Space (COPUOS)	International Global Navigation Satellite Systems (IGNSS)
UN Office of Outer Space Affairs (UNOOSA)	OECD Space Forum
Asia–Pacific Regional Space Agency Forum (APRSAF)	European Southern Observatory (ESO)
Asia–Pacific Space Cooperation Organisation (APSCO)	World Radio Congress (WRC) Responsibility of ACMA
International Astronautical Federation (IAF)/International Astronautical Congress (IAC)	Scientific Committee on Antarctic Research (SCAR)
Asia–Oceania GEOSS	International Institute for Space Law
Australasia Satellite Forum	

As space extends beyond the Government sector to private industry, the growth of commercial partnerships between global industry players and Australian industry has been encouraging.

Boeing’s partnership with Melbourne-based gaming studio, Opaque Space, for the CST-100 Starliner virtual reality astronaut training system is keeping Australia firmly ahead of the curve,⁷³ as is the recent collaboration between Airbus and Australia’s Neumann Space to provide rideshare services for small satellites and science projects to the International Space Station.

‘The Australian National Concurrent Design Facility (ANCDF) at UNSW Canberra is supported through an MOU and partnership with the French Space Agency, CNES, which is providing software and training for the facility. Opened in late 2017, the ANCDF enables spacecraft design engineers, scientists, and stakeholders to rapidly design and determine the technical and economic viability of proposed space missions.’

Lockheed Martin has recently partnered with Australia’s EOS Space Systems Pty Ltd for laser range finding, and the Lockheed Martin GMV and Inmarsat partnership with Geoscience Australia is spearheading the development of a high-accuracy satellite-based augmentation system.

We see strong potential for Australia to build on its existing partnerships, and take a leading role in building new partnerships with significant benefit for our nation now, and in the decades to come.

⁷³ <http://www.boeing.com.au/news/releases/2017/september/boeing-launches-australian-based-space-research.page>

Forming New Partnerships and Establishing Australia as a Leader

Australia's future in space as a trusted global partner involves playing an important role in ensuring safe and secure operations in space, and strengthening the international rules and laws that apply to military and commercial uses of space.

Through the coordination of the Agency, Australia can become an important leader in our region to support global efforts such as the United Nations Office for Outer Space Affairs (UNOOSA) to promote international cooperation in the peaceful uses of outer space, and maintaining the UN Register of Objects Launched into Outer Space.

As discussed in the Background of this Report, the global space industry is changing, and in tandem with the major shifts towards lower entry costs, cheaper satellites, and reusable launch vehicles, it is imperative that national and international legal regimes for space reflect the emerging complexities of the New Space Agenda.

Australia is already developing a strategic framework for the Australian space sector that supports leadership, innovation, opportunity, and entrepreneurship across the sector, along with our broader national interests following the principles set out in the *Satellite Utilisation Policy* (2013).⁷⁴ Australia can further support the efforts of COPUOS and the UNOOSA in the area of international space law.

Through Geoscience Australia, our nation is playing a lead role in the Asia–Oceania GEOSS initiative, which includes Australia, Bangladesh, China, India, Japan, Thailand, Mongolia, Myanmar, Nepal, Pakistan, and South Korea as members, and aims to provide regional coordination of Earth observation to support natural disaster management, water security, and sustainable development.

While honouring our partnerships with our allies, Australia can also strengthen its partnerships and cooperation agreements in the high-growth sector of space in the Asian region, which stands to deliver two-thirds of global economic growth in 2030.

Recommendation 5:

The Government extends existing partnership and treaty-level agreements, and establishes new partnerships to increase the participation of Australian industry and research, particularly by:

- strengthening partnerships in space to allow greater technology transfer and technology development in Australia;
- extending existing partnerships and treaty-level agreements, as well as promoting commercial arrangements to allow increased participation of Australian industry on missions;
- securing existing and establishing new ground stations and deep space communications centres in Australia;
- securing new partnership agreements with key space agencies and commercial partners in the global space sector, including in Asia and Oceania; and
- securing cooperation agreements for access to critical national (EO) data, including for weather, land and oceans, and emergency and disaster management.

⁷⁴ <https://industry.gov.au/industry/IndustrySectors/space/Publications/Pages/Australias-Satellite-Utilisation-Policy.aspx>

Chapter 5 – Industry Enablers

There has never been a better time for Australia to strengthen and expand its position in the global space market in areas of competitive advantage and market disruption. Commercialisation of new products from emerging companies creates high-tech jobs, builds experience, and bridges the participation gap between our population and the space sector.

Realising the challenge for Australia to grow its share of the global space sector requires the Government to facilitate industry growth in several key areas through:

- recognising that national innovation and education strategies are relevant to space, and that jobs in the space sector include science, technology, engineering, and mathematics (STEM), and diverse areas such as digital apprenticeships and skilled trades, medicine, law, entrepreneurship, and finance;
- international partnership agreements to increase Australian industry participation in global projects;
- industry-led collaborative research and development and commercialisation in the areas of strategic priority and leapfrog technologies. Aligning space research with space users and bridging the gap between spaceflight research and spaceflight products and services. This includes space mission projects. This includes improving access for Australian companies to international customers and supply chains;
- utilising the purchasing power of Government by emulating the work of Australian Defence Force programs and the US's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs to link large and small business to the purchasing needs of civil space-related government projects and investments in space;
- increasing industry access to shared satellite and space equipment testing facilities, and ground station infrastructure;
- easing regulatory approvals for launch and operation in space, and clarifying Australian Government requirements and obligations; and
- linking start-up and early stage Australian space companies to national and international providers of venture capital.

The recent launch of the Buccaneer cube-sat in a partnership between UNSW Canberra and Defence Science and Technology Group, and the current development by UNSW Canberra Space of three small spacecraft to demonstrate maritime surveillance technology under a AU\$10M contract from RAAF, shows the importance of government-supported space missions to grow national and industry capability. Buccaneer includes a payload led by DST Group on a cube-sat platform procured, integrated and tested by UNSW Canberra at the ANU's AITC facility. The RAAF cube-sats are being conceptualised, designed, built and tested in Canberra by UNSW Canberra Space and local industry.

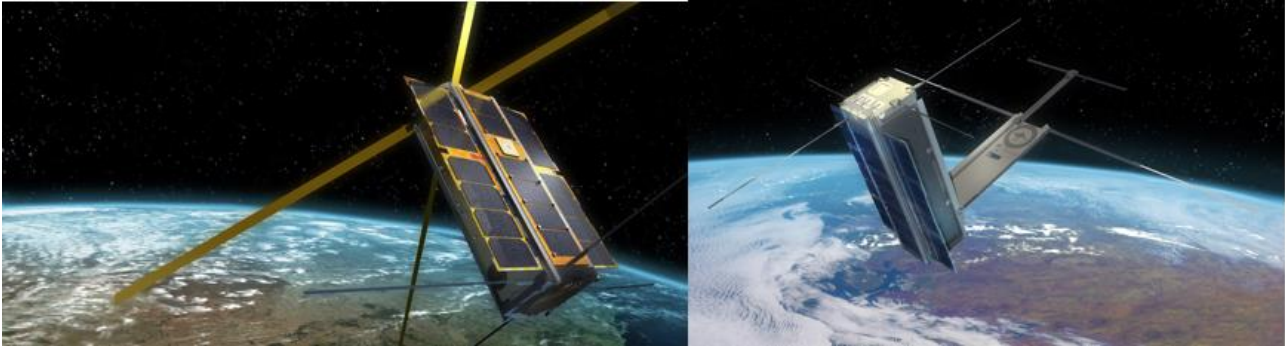


Figure 8: The Buccaneer cube-sat, developed by DST Group and UNSW Canberra Space, was launched from the US on a Delta 2 rocket in November 2017 (left) and the RAAF M1 cube-sat developed by UNSW Canberra Space is scheduled for launch in mid-2018 (right)

The research work has resulted in the formation of a spin-out company from UNSW Canberra, SkyKraft Pty Ltd, which is developing space technologies to support the needs of Defence and national security in particular, and civil and Defence needs more broadly. Such missions provide a source of inspiration for inventors, investors, and stakeholders across the nation. A nation that is inspired by achievement becomes a nation that confidently reaches for more—leading to new opportunities for STEM education, universities, careers, and a “culture of doing” that becomes the foundation of future growth.

Education and Future Workforce

The Australian space sector has strong experience in downstream services, such as satellite communication services, global positioning, and the use of satellite imagery. However, we have relatively limited experience in spaceflight services, such as manufacturing hardware and software for mission control, and on-orbit operations of space objects. A notable exception to this is Optus Satellite, which flies both its own and other companies' geostationary satellites.

Australia needs to provide spaceflight job opportunities for its university graduates. Our nation's brain drain has resulted in a shortage of flight-tested, mid-career engineers, and a depleted set of skills for making investment in the field, as well as fewer STEM students and teachers who understand the career paths in space.

The Agency's strategy for education should focus on long-term growth and sustainability. Its roles and responsibilities, as outlined in Chapter 3 and the Agency Charter (Appendix 6), include communicating Australia's role in space and its importance to the Australian economy; helping to cultivate the next generation of Australian space professionals; and strengthening the connection that young people have to space.

We support the recommendations of the Innovation and Science Australia (ISA) national strategic plan to support STEM education and training, including in disadvantaged segments of the community; to

ensure a high-quality workforce; and to improve the collaboration and innovation environment for entrepreneurs and venture capital.⁷⁵

The National Space Industry Capability Plan outlined in the Agency Charter will identify and address any critical space-related skills that are not being adequately developed, and set criteria and certification programs for future space industry workforce requirements over the next five, 10, and 20 years, in accordance with international standards.

The Agency's role in collecting data and reporting on the capability of Australia's space industry will provide guidance, and assist non-traditional space stakeholders, such as investors and Government, in making informed decisions in the space arena. It will also facilitate direct links between space companies and investors.

Suggested activities for the Agency include ensuring that the strategies of the Federal and State Departments of Education incorporate course materials based on Australian space programs for K–12 students and teachers, and link to existing young inventor programs such as the Young Scientist Awards.⁷⁶

It should also encourage the establishment of a free portal for teachers to gain access to data for use by Australian students, and financial support for domestic students, particularly from rural areas, to receive university scholarships in space-related areas, and internships with the Agency and space community.

Collaboration with Research and Development

Australia has world-class R&D skills at its universities, national research laboratories, and companies that support the space sector, despite relatively low levels of funding compared to the major space research investors such as the US, Russia, and France.

The Agency will need to ensure that there is alignment between the broader national and research investment strategies and the national space policy and strategy, particularly in areas of strategic focus.

This will ensure that prioritisation mechanisms for Australian Research Council (ARC) programs and Department of Industry, Innovation and Science Co-operative Research Programs reflect the national space policy and strategy for both fundamental research and industry collaboration. Mechanisms for collaboration with Defence, as outlined in Chapter 1, include the Defence Innovation Hub, DST Group's Next Gen Fund, and the Centre for Defence Industry Collaboration (CDIC).⁷⁷

The Agency will support collaboration between industry and the R&D community through the Industry Development Fund, as outlined in Chapter 3. This will support connections between research communities and SMEs; facilitate international partnerships and consortia in both strategic and leapfrog areas; and facilitate State and Territory hubs and initiatives and national space missions, such as satellite projects and discovery science missions.

Over time, Australia can build on its existing capability for cube-sat and microsatellite manufacture to a deeper capability in design, manufacture, and operation of complex communication and data-capture satellites. This includes new areas such as optical laser satellites and advanced sensors, such as hyperspectral scanners for Australian and Asian region markets.

⁷⁵ <https://industry.gov.au/Innovation-and-Science-Australia/Pages/2030-Plan.aspxf>

⁷⁶ <http://www.youngscientist.com.au>

⁷⁷ <http://www.defence.gov.au/WhitePaper/Docs/2016-Defence-Industry-Policy-Statement.pdf>

Commercialisation and Government as a Customer

A range of new companies are emerging in Australia (Appendix 4). Investors are taking note, with several of these companies already receiving seed to Series A funding from external investors. This speaks to the potential of Australia's space industry and the opportunity to enter the global market.

There will be a range of challenges to overcome, but the Agency, through a national capability directorate, will provide the single voice the space industry needs to link its entrepreneurs and researchers with customers.

Government investment grants and contracts that link small business directly to the innovation requirements of Government departments have a demonstrated ability to build national capability.

The best examples of this are the US Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) funds established by the Government Departments of Defence, Energy, and Health. Each fund typically provides staged investments of up to US\$150,000 in Phase I and up to US\$1,000,000 in Phase II, which may lead to full contract engagement.⁷⁸

The Australian Government's Defence Innovation Hub is an initiative of the 2016 Defence Industry Policy Statement and will invest around AU\$640 million over the decade ending 2025–2026.⁷⁹ This initiative pulls together research institutions, academia, industry, and innovative technologies, facilitating innovation from initial concept through prototyping and integrated testing. The Hub's priority for investment in the financial year of 2017–2018 includes intelligence, surveillance, reconnaissance, electronic warfare, and space and cyber security.

The Hub has already made several investments without applications that support space capabilities, for example, an investment in Quintessence Labs in the area of secure communications, and Saber Astronautics in machine learning projects.⁸⁰ These programs link small companies with the needs of Government and plug them into global supply chains, meeting the objectives of building the capability of the Australian Defence Force and maturing the Australian Defence industry.⁸¹

Similar programs across other Government departments for innovation and procurement could build innovation and capability across sectors such as agriculture, environment, and communications, and build the Australian space industry. This would support SMEs in the space value chain, including satellite manufacture and onboard sensors, equipment, and software; ground station operation; satellite fleet and constellation management; mission control and services; and the application of data from space to improve Government services. The recent ISA 2030 Plan makes similar recommendations regarding the concept of Government purchasing being a stimulus of innovation.⁸² We endorse recommendations 15 and 16 of the ISA 2030 Plan.

The Agency should ensure that the strategies and priorities for applied research at Government agencies are aligned with the national space policy and strategy. It should ensure that through innovation recommendations for the manufacturing sector, the Australia 2030: Prosperity through Innovation strategic plan builds capability for Australian small and microsatellite manufacture.⁸³

The Agency will also support the efforts of Austrade to increase the export of Australian space technology and services through its international company showcases, trade shows, and capability

⁷⁸ <https://www.sbir.gov/about/about-sbir>; <https://www.sbir.gov/about/about-sttr>

⁷⁹ 2016 Defence Innovation Policy Statement

⁸⁰ <https://www.minister.defence.gov.au/minister/christopher-pyne/media-releases/innovation-hub-boosts-australias-defence-industry-1>

⁸¹ 2016 Defence Innovation Policy Statement

⁸² <https://industry.gov.au/Innovation-and-Science-Australia/Australia-2030/Pages/default.aspx>

⁸³ <https://industry.gov.au/Innovation-and-Science-Australia/Pages/2030-Plan.aspx>

directories in order to connect start-ups and SMEs to established Australian companies with customer export channels and direct mentoring.

The benefit derived from Adelaide hosting the 68th International Astronautical Congress in September 2017 is an excellent example of such efforts.

Capital

Helping to link space companies to at least AU\$20–30 million per annum of seed and venture capital through national and global venture companies and Government-supported funds will be an important part of the Agency's roles and responsibilities. This will assist early-stage companies that specialise in space technology manufacture to move from seed to Series A funding and mature to positive cash flow from the sales of products and services.

We note the success of the AU\$10 million South Australia Early Commercialisation Fund; the CSIRO AU\$200 million Innovation Fund, managed by Main Sequence Ventures; the On Prime and On Accelerator programs; and the South Australian AU\$200 million Future Jobs Fund in funding space companies such as FluroSat, Fleet Space Technologies, and Selentium Defence. We note the Singtel Innov8 AU\$250 million venture capital arm, which also considers investment in the space industry.⁸⁴

Venture capital firms such as Black Bird Ventures, Grok Ventures, Earth Space Robotics, and UniSA Ventures have funded companies such as Gilmour Space Systems, Fleet Space Technologies, Neumann Space, and Myriota. We also note the importance of private accelerators such as the Delta-V network.

National Infrastructure

Bringing a new space product to market comes with high barriers to success. For Australians, the challenge is to turn flight prototypes into flight products and bring them to market in an internationally competitive timeframe.

Another challenge in building a portfolio of technologies that are qualified to perform in space is having sufficient access to dedicated test facilities. Current test facilities available in Australia include ANU's AITC at Mount Stromlo Observatory,⁸⁵ BAE Systems' test facilities in Adelaide's Defence Precinct,⁸⁶ and UNSW's space research facilities.⁸⁷ Test facilities in orbit are being explored, such as the recent agreement between Neumann Space and Airbus to host an Australian 100 kg instrument pod on the International Space Station.⁸⁸

While share test facilities could arguably be run on a fully commercial basis on time, there is an argument for early government stimulus to national infrastructure such as enabling commercial ground stations and shared test facilities for satellite manufacture and equipment verification.

We consulted widely on whether Australia should prioritise the building of dedicated launch facilities, with the key question of whether there is a sustained market to support such a facility.

The large high-throughput satellite (HTS) launch market is seen as well supplied, but there is potential for unmet demand for launch capacity for the cube-sat and nanosatellite market, and emerging areas such as space tourism (see Figure 2 in Chapter 1).

⁸⁴ Optus confidential submission p. 12

⁸⁵ <http://rsaa.anu.edu.au/aitc>

⁸⁶ <https://www.baesystems.com/en/our-company/our-businesses/bae-systems-australia>

⁸⁷ <http://www.unsw.adfa.edu.au/space-research/>

⁸⁸ <http://www.airbus.com/newsroom/news/en/2016/09/airbus-defence-and-space-and-australias-neumann-space-sign-first-payload-agreement-for-the-new-bartolomeo-platform-on-iss.html>

Australia may have sites suitable for development as launch sites for equatorial or lower polar orbits. We recommend that in order for commercial players to move quickly should a clear market demand arise, the Agency facilitates the regulatory approval process for launch facilities in Australia.

We also recommend that Australia investigates partner opportunities.

Facilitating Regulatory Approvals and Clarifying Obligations

As outlined in Chapter 3, an important role of the Agency will be to coordinate national space regulation in a way that provides certainty for businesses; minimises regulatory burdens and bureaucratic red tape; and otherwise assists the growth of the space industry sector and maximises its ability to innovate.

The development, testing, sale, and use of Australian spacecraft and equipment may involve several regulatory instruments, including import/export regulations, overseas launch certificates, ground stations deployment and frequency allocation regulations, ITAR regulations, CASA regulations and controls such as Australia's obligations under the Missile Technology Control Regime.⁸⁹ The facilitation and coordination of these activities will allow industries to grow faster and compete internationally. If Australia moves swiftly to facilitate regulatory approvals in the New Space arena, it could also capture a greater share of this emerging global market.

The Review notes that there are currently efforts in place to review and reform elements of the national space regulatory regime.

Similar to operations in other highly specialised industries, it will be important for the Agency to ensure that Government work-visa requirements support the development of the space industry, and allow special skilled worker migration.

Recommendation 6:

The Agency works with other Government departments across a range of portfolio areas, such as agriculture, environment, and communications, to emulate the Australian Defence Innovation Hub Investment program and the US' SBIR and STTR programs to link both large and small business to the purchasing needs for civil Government projects and investments, including the space-related investments.

Recommendation 7:

In order for commercial entities and other participants to move quickly, that the Agency facilitates regulatory approval processes for small satellite launch facilities in Australia and the launch of Australian satellites overseas, and investigates opportunities to partner with appropriate international launch providers.

Recommendation 8:

The Government gives priority to strategies that enable active engagement with Australian schools and the broader community on global space activities; space-related training and education to improve capability; space-inspired STEM outreach; and industry-led research collaboration to underpin the space industry.

⁸⁹ <https://industry.gov.au/industry/IndustrySectors/space/Pages/Legislative-arrangements-for-civil-space-activities.aspx>

Recommendation 9:

In conjunction with the Government acting on these recommendations, we call on industry to play an important role in achieving the national goals and strategies for the Australian space industry by investing in innovation to remain globally competitive; engaging with the Agency in setting strategic priorities; exploring partnerships with small- and medium-sized companies to participate in global supply chains; collaborating with research institutions; and supporting competitions for development of innovative technology, applications, and skills.

Acknowledgements

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Appendix 1 – Minister’s Press Releases

Expert Review of Australia’s Space Industry Capabilities to Participate in Global Market

13 July 2017

The Australian Government today announced it will review the nation’s space industry capability to develop a long-term plan to grow this important and exciting sector.

I am pleased to announce that the review of Australia’s space industry capability will be led by an Expert Review Group, chaired by former CSIRO chief executive Dr Megan Clark AC.

This group brings together a wealth of experience from a range of backgrounds.

The space industry sector has been growing at a compound annual growth rate of 9.52 per cent from 1998 to 2015, more than three times the annual growth rate of world GDP in the same period. Globally, revenue from space-related activities in 2015 was about US\$323 billion.

The Australian Government wants to ensure the right framework and mix of incentives are in place to assist Australia’s growing space industry sector to participate successfully in this global market.

The review will consult widely and examine Australia’s current capability and areas of comparative advantage, as well as our regional and international collaboration within the sector. Importantly, it will also consider how the space industry sector aligns with other sectors and Government priorities.

I believe that Australia can participate in the global space sector and through development of the technical capability and knowledge required for this demanding sector, we will develop skills to grow other advanced manufacturing industries in Australia.

This review is timely, given the current pace of change in the international space sector and advances in technologies that provide an environment that encourages commercial investment in space activities.

It will provide a strategic framework for the Australian space sector that supports leadership, innovation, opportunity and entrepreneurship, along with our broader national interest.

The review will commence with the first meeting of the Expert Reference Group on 20 July 2017 and will be completed by the end of March 2018.

The membership of the Expert Reference Group brings together a wealth of experience from a range of backgrounds and the Terms of Reference of the group focus on understanding the opportunities and capabilities within the space industry, as well as how the Australian space industry sector aligns with other sectors and Government priorities.

Terms of Reference for a Review of Space Industry Capability

The Australian Government (Government) has announced a review of Australia’s space industry capability which will lead to a national strategy for the sector that reflects both our developing strengths and national interests over the next decade. Ensuring that the right strategic framework is in place to support the growth of Australia’s space industry will be core to the review process.

This review builds on the existing *Australia’s Satellite Utilisation Policy* (2013) and the findings from the recently completed review of the *Space Activities Act 1998*. Reform of the space legislation is now underway to reflect advances in technologies and provide a regulatory environment that is appropriately conducive to commercial investment in the space sector. It is therefore timely for the Government to review its civil space policy and refine its strategic, long-term plans for this important sector.

The review will be undertaken under the direction of an Expert Reference Group (ERG) chaired by Dr Megan Clark AC.

Review of Australia's Space Industry Capability Terms of Reference

The Review of Australia's Space Industry Capability will build on the principles set out in the existing *Australia's Satellite Utilisation Policy* (2013) by developing a strategic framework for the Australian space sector that supports leadership, innovation, opportunity and entrepreneurship across the sector along with our broader national interests.

The Review will specifically address the following matters:

- identifying Australia's current industry capability and areas of comparative advantage for Australia to develop,
- technologies and practices that promote innovation in both the downstream (users of space technologies) and upstream (providers of space technologies) elements of space activities, particularly in areas of niche capability and competitive advantage,
- Australia's level of regional engagement and international collaboration, including identifying critical future and existing partnerships,
- identifying capability gaps to support the global competitiveness of Australian firms in the civil space sector,
- strategies to promote Australian firms engaged in the civil space sector, both domestically and internationally,
- risks and opportunities, including ongoing access to space data and associated infrastructure essential to our national interests,
- alignment with other sectors and Australian Government priorities, including Defence and cyber security, and meeting Australia's international obligations, and
- the most effective institutional arrangements to support the strategic direction of Australia's space industry

Consultations with key stakeholders and State jurisdictions will be conducted as part of this review with a focus on the matters set out above. The review will commence from July 2017 and be completed by end March 2018.

Expert Reference Group

Dr Megan Clark AC Chair

Expert Reference Group Members:

Professor Russell Boyce

Mr Michael Davis

Professor Steven Freeland

Dr Jason Held

Dr Stuart Minchin

Professor Anna Moore

Ms Flavia Tata Nardini

Dr David Williams

Mr Trevor Power (Department of Industry, Innovation and Science ex-officio)

Mr Tom Hamilton (Department of Defence ex-officio)

Media contacts: Minister Sinodinos' office 02 6277 7070

Source: <http://www.minister.industry.gov.au/ministers/sinodinos/media-releases/expert-review-australia%E2%80%99s-space-industry-capabilities-participate>

Turnbull Government to Establish National Space Agency

25 September 2017

The Turnbull Government has committed to establishing a national space agency to ensure Australia has a long-term plan to grow its domestic space industry.

Acting Minister for Industry, Innovation and Science, Senator the Hon Michaelia Cash, said the establishment of a space agency is one of the key issues being examined by the Expert Reference Group appointed to review Australia's space industry capability.

"The global space industry is growing rapidly and it's crucial that Australia is part of this growth," Minister Cash said.

"A national space agency will ensure we have a strategic long-term plan that supports the development and application of space technologies and grows our domestic space industry."

"The agency will be the anchor for our domestic coordination and the front door for our international engagement."

Former CSIRO Chief Dr Megan Clark is chairing the Reference Group, and its review is well advanced.

The Reference Group has sought views from across the country from industry, government and society, which will be used to inform our plan to expand this important and exciting sector.

The Reference Group has received almost 200 written submissions in response to its issues paper, and more than 400 people have been consulted through roundtables in each State and Territory.

Meetings have also been held with key stakeholders, including the State and Territory governments.

Feedback from the extensive consultation process has overwhelmingly shown the need for the establishment of a national space agency.

The Reference Group will now develop a charter for the space agency for inclusion in the wider strategy being brought forward by the end of March 2018.

Media contact: Minister Cash's office 02 6277 7320

Source: <http://minister.industry.gov.au/ministers/sinodinos/media-releases/turnbull-government-establish-national-space-agency>

Appendix 2: List of groups consulted and submissions; Web link to submissions

The Review met with representatives of space agencies of the US (NASA, JPL), UK, UAE, Canada (Canadian Space Agency), Germany (DLR), Japan (JAXA), New Zealand, France (CNES), and the European Space Agency, as well as representatives from USGS, Lockheed Martin, Boeing, Airbus, Thales, Raytheon Australia, Bryce Space and Technology, Spaceport Norway, Surrey Satellite Technology, SpaceX, Planet, Ariane Group, UN Office for Outer Space Affairs, RAL Space, the UK Catapult for Satellite Applications, NBN Co, US Space Weather Service, McKinsey, AECOM, Telstra, Optus Satellite and the Communications Alliance. Meetings were held with relevant Government Departments. The Review also met with portfolio agencies, Geoscience Australia, ACMA, CSIRO, the Bureau of Meteorology, DST Group, the Academy of Technological Sciences and Engineering, the Forum of Australian Chief Scientists, and several universities.

A list of submissions received are shown below. A number of confidential submissions to the Review were received but not listed below. A web link to the non-confidential submissions is provided here.

https://consult.industry.gov.au/space-activities/review-of-australian-space-industry-capability/consultation/published_select_respondent

Submissions to the Review of Australia's Space Industry Capability

Submissions from:
2026 Spatial Industry Transformation and Growth Agenda (2026Agenda)
ACT Government Treasury and Economic Development Directorate
Adelaide Law School University of Adelaide
Adrian James – UCL Australia and MSSL Australia
AECOM
American Institute of Aeronautics and Astronautics (AIAA) - Adelaide Section
Amy Parker – Curtin University
Andrea Boyd - ESA
Andrew Dempster – UNSW
Andrew Hyslop - Vitrociset Belgium Contractor for ESA/ESTEC
Andrew Skidmore - University Twente & Macquarie University
Anthony Milne – UNSW
Asia Pacific Aerospace Consultants (APAC)
Astronomy Australia Limited (AAL)
Aude Vignelles - Soliton Network Consulting
Australasian Society for Aerospace Medicine (ASAM)

Submissions from:
Australia Space Launch
Australian Academy of Technology and Engineering (ATSE)
Australian Antarctic Division
Australian Communications & Media Authority (ACMA)
Australian Earth Observation Community Coordination Group (AEOCCG)
Australian Government Earth Observations from Space Working Group
Australian National University (ANU)
Australian Nuclear Science and Technology Organisation (ANSTO)
Australian Research Council (ARC)
Australian Strategic Air Traffic Management Group (ASTRA)
Australian Strategic Policy Institute (ASPI)
Australian Youth Aerospace Association (AYAA)
BAE Systems Australia
Ben Greene - EOS, and CRC for space environment research
Blackmagic Design
Boeing Australia
Brian O'Brien – Brien J. O'Brien & Associates Pty Ltd, and University of WA
Bureau of Meteorology (BoM)
Carolyn McGregor – University of Ontario Institute of Technology
Casey Handmer – Hyperloop One
Cedric Muller – ION Group
Chris Howitt – Queensland Ambulance Service
Clearbox Systems
CRC for Spatial Information
Cristian Englert – ESA
Cristina Cerioni - International Space University, The Netherlands
Curtin University
Danvers Flett

Submissions from:
David Ball – Space Industry Association of Australia
Defence Materials Technology Centre (DTMC)
Deklan Soeroes – Le Fevre High School
Department of Communications and the Arts
Department of Infrastructure and Regional Development
Dipak Paudyal – Esri Australia & UQ
Dylan O'Donnell – Thomas O'Donnell Pty Ltd
Emile Victor – Airbus/ESA
Equatorial Launch Australia (ELA)
ESSWeathertech Pty Ltd
Fleet Space Technologies
Geoscience Australia (GA)
Gilmour space technologies
Glen Nagle – CSIRO
Graciela Metternicht – UNSW
Gregory Cohen – Western Sydney University
Gregory Rowlands
Hugh Carrigg Aerospace
Igor Levchenko – QUT and Nanyang Technology University
Inovor Technologies
International Centre for Radio Astronomy Research (ICRAR)
James Murtagh – Australian Taxation Office
Jennes Walker – Industry Capability Network
Jeto Lab
John Crane – Southern Astronomy Society
John Newell
John Trinder – University of NSW
Jonathan Lim – Monash University

Submissions from:
Katherine Pegg - Airbus Defence & Space GmbH
Kevin Gallagher – Port Macquarie Astronomical Association Inc.
Landgate
Leo Ng
Liam Murphy – Gilmour Space Technologies
Lockheed Martin
Maitec
Mark Kayne Joseph Podesta
Mark Meegan
Mars Society Australia
Mathew McGann – Health Horizon
Melbourne Space Program
Michael Hewson – Central Queensland University
Moody Space Centre
MoonshotX
Natalie Caruso – Southern Astronomical Society
National Committee for Space and Radio Science Academy of Science
Neil Dunbar – Airbus Defence and Space UK
Neumann Space Pty Ltd
Noor Taofiq Huq - Australian Centre for Space Engineering Research University of NSW
Nova Systems
NSW Department of Industry
NT Government Department of Trade, Business and Innovation
Outback Astronomy (NSW)
Ozius
Paul van Staden
Peter Lieverdink

Submissions from:
Peter Teague – Vipac Engineers and Scientists Ltd
Picosat Systems Pty Ltd (PS)
Planetary Research Centre Macquarie University
Planetary Science Community Curtin University
Products For Industry (PFI)
Regional Development Australia (RDA)
Rio Tinto
Ripple Aerospace
Robert Hunt – International Space University, Perth Observatory, and Swinburne University of Technology
Roger Franzen – Earthspace
Rowena Christiansen – University of Melbourne
Rowena Eastick – Department of Environment and Natural Resources
SA Government
Satellite Services Working Group (SSWG) Communications Alliance Ltd
Science and Technology Australia (STA)
Senator Linda Reynolds – Parliament of Australia (WA)
Shoal Engineering Pty Ltd
Skyborne Technologies
Small World Communications
SMS Consulting Group Ltd
Solinnov Pty Ltd
Southern Launch
Space Association of Australia Inc.
Space Generation Advisory Council (SGAC)
Space Industry Association of Australia (SIAA)
Space Law and Strategy for International Aerospace Law and Policy Group
Space Mission Advisory Centre

Submissions from:
Space Ops Australia
Space Weather Services (SWS) BoM
Stephen Bornstein – Space consultant (former Rocket Lab engineer)
Telstra
Thales Australia
Triggar
University of New South Wales (UNSW)
University of Queensland (UQ)
University of South Australia
University of Sydney
University of Tasmania
Vice Chancellor’s Ancora Imparo Leadership Program Monash University
WA Government
Warwick Holmes – University of Sydney

Public Consultations, Review of Australia’s Space Industry Capability

Roundtables

24 August 2017: Hobart

31 August 2017: Darwin

1 September 2017: Brisbane

5 September 2017: Perth

6 September 2017: Adelaide

7 September 2017: Melbourne

11 September 2017: Canberra

13 September 2017: Sydney

Other Meetings

Throughout the review process, the Chair and Members of the ERG also participated in a range of other meetings with a broad range of stakeholders, including industry groups, research organisations and State and Territory Governments.

Extensive consultation was also undertaken by the Chair and Members of the ERG with a wide range of groups as part of the International Astronautical Congress held in Adelaide between 25-29 September

2017. The Chair presented an update on the review to the COAG Industry and Skills Council on 4 August 2017.⁹⁰ The Chair and other ERG Members also made presentations to a wide range of other forums during the course of review.

⁹⁰ <https://industry.gov.au/AboutUs/Documents/COAG-Industry-and-Skills-Council/4%20August%202017%20-%20COAG%20Industry%20and%20Skills%20Communique.pdf>

Appendix 3: Interim Report by the ERG to Minister Sinodinos on 14 September 2017

Review of Australia's Space Industry Capability - Expert Reference Group's Preliminary Report -

The review of Australia's space industry capability has reached an important milestone. The consultation process concluded on 13 September with almost 200 written submissions and over 400 people consulted, through roundtable meetings in every State and Territory as well as meetings with State and Territory governments. Meetings have also been held with Defence, major aerospace companies, communications groups, and the Earth observation community.

What is already clear is that Australia has billions of dollars' worth of space-related existing infrastructure and facilities, a vibrant community of over 50 small companies and over 40 medium-sized companies active in the space sector. Australia has world-leading capability including in research, satellite data analysis, radar and radio communications, and several emerging areas of strength. There is also positive public awareness of the benefits derived from space and its 'enabler' function in driving the productivity of the broader economy.

What we have been consistently hearing from all stakeholders is that, to further enable the industry to capitalise on our strengths nationally and internationally, there is a need for a single point of contact for domestic and international partnerships, greater national coordination and strategic direction, government support to enable industry to participate in global supply chains, and a whole-of-government approach to the space sector.

In particular, the national consultation is calling for a space agency with the authority to coordinate Australia's space activity and progress identified priorities. It is important that the agency has long-term continuity. The nation is calling on the agency to focus on the following needs:

1. **A national strategy that builds on our strengths and identifies areas of focus for Australia in the space sector.** There is a need for a long-term plan for Australia that addresses critical space-related dependencies and supports the development innovative space technologies and applications to grow Australia's space industry.
 - a. It is becoming clear that every area of Australia's economic and social wellbeing is becoming reliant on the application of space technologies, particularly through the effective use of satellite data.
 - b. The space sector is a productivity enabler for many other sectors of our economy and has the potential for commercial growth in its own right.
 - c. There are opportunities available to Australia in the global space sector that need careful consideration and strategic industry development.
2. **The coordination of domestic activities in Australia's space sector.** There is also an opportunity to leverage greater benefits from Australia's space industry through specific collaboration among State/Territory governments and the Commonwealth.
 - a. The Australian Government has a key role to ensure that Australia has the space capabilities to meet its strategic needs. In particular, better coordinated provision and access to test facilities and ground infrastructure.
 - b. Australia has space-related dependencies throughout our economy and the Australian Government has a role in managing risks associated these dependencies.
 - c. There is an opportunity to leverage greater benefit through better coordination among both Commonwealth agencies and States/Territories.

3. **A single point of contact for international engagement and partnerships.** There is a need for a clear point of contact within the Australian Government that can actively engage with global partners to maintain critical partnerships and broker future space opportunities.
 - a. Space activities are global in their nature and scope, Australia must leverage international partnerships to meet its space objectives.
 - b. Australia benefits greatly from international partnerships but there is an urgent need to invest in maintaining these partnerships.
 - c. The changing nature of the space industry environment requires Australia to cultivate new partnerships with emerging space actors, both sovereign and commercial.
 - d. Clarity is needed at the national level to provide a single point of contact and coordination for stakeholders – both domestic and international – to discuss space opportunities.
4. **Support to develop Australia's space industry capability.** While the above needs have been clearly identified at this point of the review, there is further research required to identify the best mechanisms to support industry and define clear focus areas for that support. This will be undertaken in the ongoing work of the review. We do however note the positive engagement that is occurring between Defence and research and industry in space-related technologies through the Defence Next Generation Fund and the Defence Innovation Hub.

With the coherent view on the focus areas outlined above there is also clarity that any space agency should be modest, forward-looking and agile. There is no call for an agency to take over the operational and regulatory activities currently being undertaken effectively by other existing authorities. We believe that the future direction in space is in partnership with the private sector, as has been demonstrated through the Canadian and UK space programs.

While noting that the review still has significant further work to undertake to develop its final strategy document, to be provided to Government in March 2018, the ERG consider it would be appropriate for the Australian Government to consider the early announcement of a space agency to address the above identified needs, with detail to be developed in the final strategy to government.

Appendix 4: Snapshot of Australian space companies whose activities were reviewed as part of this Review

4a: Start-ups and small to medium-sized companies

Company name	Company website
2SG Technology Group	http://www.2sg.com.au/
Additive Rocket Corporation	http://arc-engines.com/
Arlula	https://www.arlula.com/
Au Launch Services	No website
Auspex Strategic Advisory	No website
Australia Space Launch Pty Ltd	No website
BigMate	www.bigmate.com.au
Coutts Communication	http://www.couttscommunications.com/
Delta-V Newspace Alliance	http://www.deltavspacehub.com/
Embedded GNSS Pty Ltd	No website
Equatorial Launch Australia	https://ela.space/
Etiam Engineering Pty Ltd	www.etiam-engineering.com
Fleet Space Technologies	http://www.fleet.space/
FluroSat	https://www.flurosat.com/
HEO Robotics	https://www.heo-robotics.com/
Hypercubes	http://www.hypercubes.global/
Geospatial Intelligence Pty Ltd	https://geoint.com.au/
Gilmour Space Technologies	https://www.gspacetech.com/
GIS People	http://www.gispeople.com.au
Glassy Metal Technologies Limited	No website
Heliaq Advanced Engineering	http://heliaq.com/
Virgin Hyperloop One	https://hyperloop-one.com
Hypersonix Pty Ltd	No website
HyVista Pty Ltd	http://www.hyvista.com/

Company name	Company website
Integrated data networks	http://idnaust.com.au/
Integrated Systems Solutions	http://www.isscloud.net/
Innovative Electronics Pty Ltd	http://ieau.com.au/
Inovor Technologies Pty Ltd	https://www.inovor.com.au/
Irriscan	http://irriscanaustralia.com.au/
Launchbox	http://www.launchboxspace.com/
Liquid instruments	http://www.liquidinstruments.com/
Maitec	http://www.maitec.com.au
Melbourne Space Program	http://www.melbournespace.org/projects/
Moody Space Centre	http://www.moodyspacecentre.com
MoonshotX	www.moonshotspace.co
Myriota	http://myriota.com/
NavAids	http://navaids.com.au/
Neovation Advisory Pty Ltd	No website
Neumann Space	http://neumannspace.com/
NextAero	http://nextaero.com.au/projectx/
NodeSat	http://nodesat.com
Opaque Space	https://www.opx.space/
Ovass	http://www.ovass.com/
Ozius	http://www.ozius.com.au/
Podtrackers	https://www.podtrackers.com/
PNT Consulting	No website
PicoSat Systems	http://picosat.systems/
ResearchSat	http://researchsat.com/
Ripple Aerospace	https://rippleaerospace.com/
Saber Astronautics	http://www.saberastro.com
Seaskip Pty Ltd	No website

Company name	Company website
Silentium Defence	www.silentiumdefence.com.au
SkyKraft Pty Ltd	http://skykraft.com.au/
Solinov	http://www.solinnov.com.au/
Southern Launch	www.southernlaunch.space
Space Ops Australia	http://spaceops.com.au/
Speed3D	www.spee3d.com
Station Innovation	http://www.stationinnovation.com.au
Teakle Composites	http://www.teaklecomposites.com.au/
Toolcraft	www.toolcraft.com.au
Triggar	http://triggar.com.au
Quintessence Labs	https://www.quintessencelabs.com

4b: Established Australian Companies

Company name	Company website
AAM	http://www.aamgroup.com/
Activ8me	www.activ8me.net.au
Agile Communications	http://www.agile.com.au/
Amaero Additive Manufacturing	http://www.amaero.com.au
Asia Pacific Aerospace Consultants	http://www.apac.com.au/
Auspace	http://auspace.com.au/
A.W. Bell	http://www.awbell.com.au
Axiom Precision Manufacturing	www.axiompm.com.au
Bordernet	www.bordernet.com.au
Brenco Group	www.brenco.com.au
CEA Technologies	http://www.cea.com.au
Chime Communications Pty Ltd (iinet)	www.iinet.net.au
Clearbox Systems	http://www.clearboxsystems.com.au/
Clear Networks	https://www.clear.com.au/
Cobham Aviation Services	http://www.cobhamaviationservices.com
DefendTex	www.defendtex.com
EM Solutions	http://www.emsolutions.com.au/
EOS Electro Optic Systems	http://www.eos-aus.com
ESS Weathertech Pty Ltd; ESS Earth Science	http://www.essweather.com/
Geoimage	https://www.geoimage.com.au/
Geoplex	http://geoplex.com.au/
GPSAT Systems Australia	http://gpsatsys.com.au
Hills	http://corporate.hills.com.au
Foxtel and Austar	https://www.foxtel.com.au/index.html
Ipstar	http://ipstarbroadband.com.au
Inabox Group	https://www.inaboxgroup.com.au/
Jim's Antennas	https://www.jimsantennas.com.au/

Company name	Company website
Locata	http://www.locata.com
Masters and Young	http://www.masters-young.com.au/
NBN Co	https://www.nbnco.com.au
NGIS	www.ngis.com.au
Nova Group	www.novagroup.com.au
Nova Systems	http://novasystems.com/
Omnispace	www.omnispace.com
Otus Intelligence Group	http://www.otusintel.com/
Orion Satellite Systems	www.orionsat.com.au
OrbitAustralia	http://www.orbitaustralia.com/products.html
OzSat	www.ozsat.com.au
Pivotel	www.pivotel.com.au
Position Partners Pty Ltd	https://www.positionpartners.com.au/
Practical Systems Pty Ltd	https://www.practicalsystems.com.au/farm-software/farmmap/
Primus Telecommunications	www.iprimus.com.au
Quickstep	http://www.quickstep.com.au/
SatPlus Australia (Queenland Satellites)	www.satplus.com.au ; http://www.queenslandsatellites.com.au/
Singtel Optus Pty Limited Optus Satellite Pty Limited	http://www.optus.com.au
Skybridge Group Pty Ltd	www.skybridge.com.au
SES	https://www.ses.com/
Silanna Semiconductor	https://www.silanna.com/
Sky and Space Global	https://www.skyandspace.global/
Skymesh	www.skymesh.net.au
Shoal Engineering	http://www.shoalgroup.com
Small World Communications	http://www.sworld.com.au/
Speedcast International	https://www.speedcast.com

Company name	Company website
TAE Aerospace	http://www.taeaerospace.com
Telstra	https://www.telstra.com.au/
Tidetech Commercial Marine	www.tidetechmarinedata.com
TopCon	https://www.topconpositioning.com/
UGL Limited	http://www.ugllimited.com
URSIS (Cygnus Satellite)	http://ursys.com.au/

4c: International companies

Company name	Company website
ABS	http://www.absatellite.com/
Airbus	http://www.airbus.com/
AON	http://www.aon.com/
BAE Systems Australia (Holdings) Limited	https://www.baesystems.com/en-aus/home
Boeing Australia Holdings Pty Ltd	http://www.boeing.com.au/
Cobham Aviation Services	http://www.cobhamaviationservices.com/
GE (Satellite Tracking Systems)	
Globecast	https://www.globecast.com/
Google Australia	https://www.google.com.au/
Intelsat	http://www.intelsat.com/
Interorbital Systems	www.interorbital.com/
Inmarsat	https://www.inmarsat.com/
ITC Global	www.itcglobal.net.au/
IPSTAR (wholly owned by Thaicom Public Company Limited)	www.ipstar.com
Lockheed Martin	https://www.lockheedmartin.com
SES New Skies Satellites Australia Pty Ptd	http://www.ses.com
Northrop Grumman	http://www.northropgrumman.com/
OHB-System AG	https://www.ohb-system.de/
Omnispace LLC	https://omnispace.com/
Panasonic (ICT Global)	http://www.itcglobal.net.au/
Raytheon	https://www.raytheon.com/au/
Saab Australia	https://saab.com/region/saab-australia/
Safran	https://www.safran-group.com/
SES	https://www.ses.com/
SSL	https://www.sslmda.com/

Company name	Company website
SpaceX	http://www.spacex.com/
Thales Alenia Space	https://www.thalesgroup.com/en/global/activities/space
TopCon Corporation	http://global.topcon.com/
Trimble	http://www.trimble.com/
VT iDirect	http://www.idirect.net/
Viasat Inc	https://www.viasat.com/

Appendix 5: Snapshot of Space Research in Australia

Table 1: EDUCATION, STUDENT BODIES, PROFESSIONAL ORGANISATIONS

Group/Program name	Acronym; Host Institution	Website
Victorian Space Science Education Centre	VSSEC	https://www.vssec.vic.edu.au
Young Scientists of Australia		http://www.ysa.org.au
Young Scientists Awards of Australia		http://www.youngscientist.com.au
Science Teacher's Association of NSW		http://www.stansw.asn.au
Australian Science Teacher's Association		http://asta.edu.au
Australian Youth Aerospace Association Inc.	AYAA	https://ayaa.com.au
Southern Hemisphere Space Studies Program		http://www.unisa.edu.au/IT-Engineering-and-the-Environment/Division-Information-Technology-Engineering-and-the-Environment/Southern-Hemisphere-Summer-Space-Program1/
Melbourne Space Program		http://melbournespace.org/about-us/
Science and Technology Australia		https://scienceandtechnologyaustralia.org.au/
Australian Academy of Technology and Engineering	ATSE	https://www.atse.org.au
National Committee for Space and Radio Science	NCRS	No website
Mars Society Australia		http://www.marssociety.org.au
Australian Academy of Science	AAS	https://www.science.org.au

GOVERNMENT AGENCY - DEFENCE

Agency	Acronym	Website
Australian Geospatial Intelligence Organisation	AGO	http://www.defence.gov.au/AGO/
Defence Material Technology Centre DMTC	DMTC	No website
Defence Science and Technology Group	DSTG	https://www.dst.defence.gov.au

CRC's, NCRIS FACILITIES, ARC-FUNDED CENTRES, TRAINING HUBS WITH INDUSTRY RELATING TO SPACE

Group Name	Host institution	Website
CRC for Spatial Information		http://www.crcsi.com.au; http://www.nrmhub.com.au
Space Environments Management CRC	SERC; ANU	
The Australian National Fabrication Facility (ANFF)	ANFF	http://www.anff.org.au
Satellite Positioning for Atmosphere, Climate and Environment (SPACE) Research Centre	SPACE; RMIT	
ARC Training Centre for Cubesats, UAV and their Applications	Uni Sydney	https://sydney.edu.au/research/spacenet/news-events/20170608.shtml
Centre for Quantum Computation and Communication Technology	UNSW	http://www.cqc2t.org/
ARC CoE for All Sky Astrophysics CAASTRO	CAASTRO; Univ Sydney	http://www.caastro.org

Group Name	Host institution	Website
ARC CoE Graviational Waves	Swinburne University of Technology	http://www.ozgrav.org
ARC CoE All Sky Astrophysics in 3D (ASTRO3D)	ANU - Mt Stromlo	http://astro3d.org.au

RESEARCH GROUPS, JVs, CONSORTIA RELATING TO SPACE

Research Group	Collaborators	Website
International Centre for Radio Astronomy Research (ICRAR)	ICRAR: Curtin and UWA	https://www.icrar.org
Australian Centre of Space Engineering Research ACSEr	University of NSW	http://www.acser.unsw.edu.au
Advanced Instrumental Technology Centre	AITC; ANU - Mt Stromlo	http://rsaa.anu.edu.au/aitc
Australia's Earth Observation Community Coordination Group	Univ Queensland	https://www.eoa.org.au
Astronomy Australia Ltd.		http://www.astronomyaustralia.org.au
Space Mission Advisory Committee (SMAC)		
Space Life Science Committee of the Australasian Society of Aerospace Medicine		https://www.asam.org.au/aims

Universities

Unviersity	Website
ANU	http://www.anu.edu.au
Curtin University	http://www.curtin.edu.au

Unviersity	Website
Macquarie University	https://www.mq.edu.au
Swinburne University of Technology	http://www.swinburne.edu.au
UniSA	http://www.unisa.edu.au
University of Adelaide+C58	https://www.adelaide.edu.au
University of Newcastle	https://www.newcastle.edu.au
University of NSW	https://www.unsw.edu.au
University of Sydney	https://sydney.edu.au
University of Tasmania	http://www.utas.edu.au
University Queensland	https://www.uq.edu.au
University of Western Australia	https://www.uwa.edu.au
Western Sydney University	https://www.westernsydney.edu.au/

Appendix 6: Agency Charter

Purpose of the Agency

The Australian Space Agency ('Agency') will be the front door for Australia's international engagement in space, operate as the national priority-setting mechanism for space, enhance Australia's domestic coordination in space and, supported by world-class science and research, facilitate the growth and maturing of the Australian space industry sector. It will provide a single, whole-of-government voice for Australia's civil activities and ambitions in space. The Agency will ensure that Australia's activities and ambitions in space contribute to productivity, competitiveness and employment across the Australian economy, further enhance and secure new knowledge and capability, and benefit and inspire all Australians.

Roles and Responsibilities of the Agency

To act as a single focal point by:

- Developing and implementing an International Engagement Plan which sets out critical international and national partnerships consistent with Australia's national objectives;
- Working on international and national civil space projects in cooperation and collaboration with national industry and the research sector;
- Ensuring access to space data sets that critically underpin the security and integrity of national infrastructure, emergency and weather services;
- Maintaining knowledge and expertise to act both as a trusted advisor to government on space-related activities and as a trusted broker to the broader space sector, in order to facilitate appropriate space-related activities.

To act as a whole-of-government agency and a single voice by:

- Coordinating whole-of-government and inter-government policy to provide a single voice for the Australian civil space sector activities and ambitions;
- Determining and recommending to Government where civil space-related government investment could best be directed across the Commonwealth. This includes ensuring that States and Territories and agencies within the national space community have appropriately integrated strategies that are aligned with the National Space Industry Capability Plan (see below);
- Ensuring appropriate alignment to national defence and security policy;
- Regulating Australian space activities under the *Space Activities Act 1998* (Cth), or any replacement and/or amended civil space legislation, and aligning the national regulatory framework for space-related activities as far as possible with other relevant legislative frameworks;
- Coordinating national space regulation in a way that provides certainty for business, minimises regulatory burdens and bureaucratic red-tape and otherwise assists the growth of the industry sector and maximises industry's ability to innovate, including through collaboration between the industry and research sectors;
- Leading negotiations regarding relevant bilateral and international civil space, which may include specific technology safeguards agreements;
- Supporting the Department of Foreign Affairs and Trade as required from time to time on international treaty processes, legal, security and bilateral trade relations, and the continued implementation of Australia's commitments under the five UN Space Treaties so as to help build and support widely accepted behavioural norms in space; and

- Ensuring that Australia's interests are fully represented at appropriate international forums on space and space-related activities.

To grow Australia's space industry sector by:

- Developing and leading Australia's national policy and strategy to expand the space sector and to help further diversify and grow the Australian economy;
- Consulting with the heads of relevant agencies, departments, State and Territory Governments, industry, the science and research community and other relevant stakeholders as it develops the national strategy and policy;
- Developing and implementing a National Space Industry Capability Plan⁹¹ that identifies existing opportunities for Australia, as well as new and emerging areas where Australia could become a world leader, and which ensures that the interests of Australian business remain at the forefront of Government policy directed towards space-related activities;
- Developing and proposing, as part of the national policy and strategy, capital investment every 3-4 years in a major space mission, which may include national satellite projects that help meet national terrestrial and marine needs and/or discovery science missions; and
- Encouraging close and effective Commonwealth–State cooperation in the development of Australia's space industry capabilities.

To provide an effective evidence base for Australia's space capability and industry by:

- Collecting data and reporting every [two] years on the capability of Australia's space industry, including clear evidence of performance in the space sector, national research strengths, ground and space assets and space sector ecosystem mapping;
- Ensuring that data and analysis provided to Government represents a more effective evidence base for the design, delivery and evaluation of Government-supported programs in space;
- Providing an Annual Report to Parliament on Australia's civil space sector which will include an evidence base for assessing progress against the performance measures set out in the national policy and strategy; and
- Developing and publishing every [two] years a Capability Directorate of the national civil space sector.

To inspire the nation by:

- Effectively communicating Australia's role in space and its importance to the Australian economy, and improving the security, safety and living standards of all Australians;
- Strengthening the connection that children and young people and their parents have to space, sparking their curiosity and entrepreneurial spirit and expanding their knowledge and interest in space and STEM subjects;
- Cultivating the next generation of Australian space professionals by promoting space education and projects in the community and supporting the jobs of the future in space-related sectors and the use of space technology in the broader economy;
- Setting appropriate national workforce goals for the engagement of Australian space professionals for the next 5, 10 and 50 year timeframes; and
- Building national pride in Australia's role in space missions, satellite projects and discovery science missions.

⁹¹ The National Space Industry Capability Plan will ensure that Australia develops and retains strategic capability in space. This will include the capability to design, test, maintain, sustain, enhance and develop space-based technologies, ground assets, science and appropriate space-related applications. It will encourage further collaboration involving industry and research and include a roadmap to develop capability over time.

Structure and Governance

The Space Agency is a whole-of-government entity. It will be established immediately under interim arrangements to transition to a statutory agency as soon as practical, with its Charter embedded in enabling legislation. It will be led by a Head of the Agency ('Agency Head') under the following terms:

- The Agency Head is appointed by Minister with portfolio responsibility for civil space activities;
- The Agency Head will seek appropriate advice through the establishment of a Space Industry Leaders Group and a National Space Advisory Forum;
- The Agency Head is supported by a Steering Board responsible to the Minister for oversight and advice to the Minister on the appointment of the Agency Head, strategy, governance and performance of the Agency. The Steering Board will meet at least quarterly and will comprise four independent members, one of whom will be the Chairperson and two of which will have relevant industry skills and expertise. It will also include the Secretary of the relevant portfolio department or their deputy who has responsibility for the Agency, and the Agency Head; and
- The Agency Head will report twice yearly to the relevant sub-committee of Cabinet to support its role as a whole-of-government agency.

Appendix 7: Web Link to Analytical Reports

- ACIL ALLEN Australian Space Industry Capability
- Bryce Space and Technology, 2017a: Global Space industry Dynamics
- Bryce Space and Technology, 2017b: Global Space Strategies and Dynamics
- These reports are published and can be found via the web link below.

<https://industry.gov.au/industry/IndustrySectors/space/Pages/Review-of-Australian-Space-Industry-Capability.aspx>

Appendix 8: Acronyms and abbreviations

CDIC: Centre for Defence Industry Collaboration

CNES: French Space Agency

EO: Earth observation

ESA: European Space Agency

EUMETSAT: European Organisation for the Exploitation of Meteorological Satellites

GEO: geostationary orbit

GNSS: global navigation satellite services

HTS: high-throughput satellites

IoT: Internet of things

ISA: Innovation and Science Australia

LEO: low Earth orbit

MEO: medium Earth orbit

NASA: National Aeronautics and Space Administration

R&D: research and development

SBIR: Small Business Innovation Research

SES: Societe Europeenne de Satellite

SpaceX: Space Exploration Technologies

SSA: Space Situational Awareness

STEM: science, technology, engineering and mathematics

STTR: Small Business Technology Transfer

UK: United Kingdom

ULA: United Launch Alliance

UN: United Nations

UNOOSA: United Nations Office for Outer Space Affairs