

ACIL ALLEN

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Report to Department of Industry, Innovation and Science

Australian Space Industry Capability

A Review



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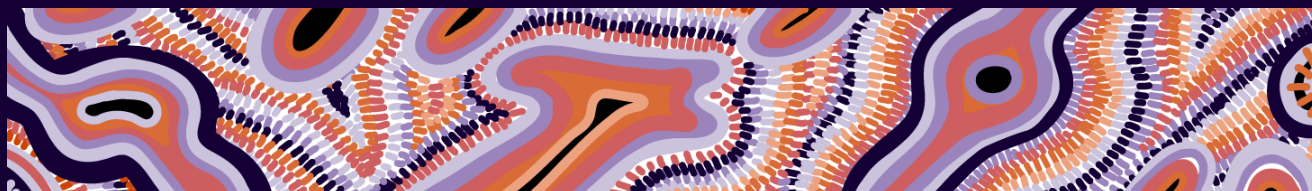
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ACIL Allen acknowledges Aboriginal and Torres Strait Islander peoples as the Traditional Custodians of the land and its waters. We pay our respects to Elders, past and present, and to the youth, for the future. We extend this to all Aboriginal and Torres Strait Islander peoples reading this report.



Goomup, by Jarni McGuire

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Glossary

ACSER	Australian Centre Space Engineering Research
Additive engineering	3D printing and related manufacturing
AITC	Advanced Instrumentation and Technology Centre
ANGSTT	Australian National Ground Segment Technical Centre
ANU	Australian National University
AQUA	International Earth Science satellite mission centred at NASA and involving JAXA and INPE
ATNF	Australian Telescope National Facility
BOM	Bureau of Meteorology
CDSCC	Canberra Deep Space Communication Complex
CNES	The Centre National d'Etudes Spatiales
CDF	Concurrent Design Facility
CRCSI	Cooperative Research Centre for Spatial Information
CSA	Canadian Space Agency
CSIRO	Commonwealth Science and Industrial Research Organisation
DIIS	Department of Industry, Innovation and Science (DIIS)
DLR	German Aerospace Centre
DST	Defence Science and Technology Group
ELA	Equatorial Launch Australia
EOS	Electro Optic Systems a company operating in Australian and also Earth Observations from Space
ESA	European Space Agency
FTE	Full time equivalent

GA	Geosciences Australia
GMT	Giant Magellan Telescope
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
INPE	Instituto Nacional de Pesquisas Espaciais
IP	Intellectual property
ITR	Institute for Telecommunications Research
JAXA	Japan Aerospace Exploration Agency
LEO	Low Earth Orbit
MRO	Murchison Radio-astronomy Observatory
NBN	National Broadband Network
NCI	National Computational Infrastructure
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPP	National Polar-orbiting Partnership
OECD	Organisation for Economic Co-operation and Development
PIGI	The Predictive Ground Station Project
PNT	Position, Navigation and Timing
RAAF	Royal Australian Air Force
SAR	Synthetic Aperture Radar
SBAS	Space Based Augmentation System
SKA	Square Kilometre Array
SERC	Space Environmental Research Centre
SLR	Satellite Laser Ranging
SME	Small and Medium Sized Enterprises
STEM	Science, Technology, Engineering, Maths
SSA	Space Situational Awareness
TT&C	Telemetry, Tracking and Command
TERRA	Earth Observing System's flagship satellite "Terra" launched by NASA

UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UKSA	United Kingdom Space Agency
UNSW	University of New South Wales
US	United States
WA	Western Australia

Executive summary

The space industry in Australia generates total revenues of around \$3 billion to \$4 billion and employs around 10,000 full time equivalents. It comprises around 388 companies, 56 education and research institutions and directly involves around 24 government agencies.

Capabilities

Australia has capabilities along most of the space industry supply chain. By far the strongest areas are in applications where Australia has experience in integrating space sourced data into communications, Earth Observations from Space and Global Navigational Satellite Services (GNSS).

Manufacturing

Australia has no capability in the manufacture of large satellites and limited capability in design and specification of launch vehicles. However it does have capability in the specification and design of communications satellites through Optus and an emerging capability in the design and manufacture of nano- and micro-satellites in universities and emerging start-up companies.

Manufacturing of satellite sub-systems is an emerging capability that has good prospects. This includes high performance optics, radio communications systems, optical communications systems and on-board data handling. Many of these activities build on Australia's capability in the manufacture of ground-based optical systems for astronomy, satellite laser ranging and space debris tracking.

Space operations

Optus Satellites has over 30 years' experience in the operation of communications satellites. Australian based companies are also strong in telemetry, tracking and command for satellite operations. Several Australian Universities also have satellite operation capabilities; including ground stations to support nano-satellite missions.

Australian government agencies have well established ground station networks and infrastructure supporting Earth Observations from Space, meteorology, deep space exploration and astronomy. The private sector also has ground stations to support operations for communications, earth observations from space and GNSS.

Capability in satellite laser ranging for tracking operating satellites and space debris has been established at Mount Stromlo. Australia is well located to support low earth orbit satellite launches. An Australian company is working on establishing a launch complex in the Northern Territory.

Australia possesses advanced capabilities in astronomy including the Square Kilometre Array project in Western Australia.

Applications

Australia's has particular strengths in space applications. Sectors such as agriculture, mining, logistics, aviation and communications depend on space derived services for communications, imagery and positioning.

Satellite communications is a major capability in Australia. Australian based firms also have strong capabilities in communication systems and in research into photonics, quantum cryptography, optical design and adaptive optics.

There is also major capability in integration of space derived imagery into many applications including weather forecasting, vegetation and land use monitoring, national security, emergency services and surveying and mapping.

There are strong capabilities in Government agencies in the management and publishing of data derived from space. Geoscience Australia's Digital Earth Australia is receiving international recognition. The private sector is also moving to similar cloud based systems.

There is an emerging capability in manoeuvring and managing space debris through the work of the Space Environment Research Centre at Mount Stromlo.

Ancillary services

Australia has well-developed technical consulting, legal, marketing and regulatory capabilities in communication satellites and systems. These capabilities are not as strong as the ones in other areas.

Alignment with other sectors of the Australian Economy

The Australian space industry is embedded in most areas of the Australian economy. Australian capabilities overlap with space industry capability in many areas. Industries such as services (predominantly financial), construction, mining, transport, manufacturing and agriculture are likely to continue to benefit from and add to space industry capability. Many of these industries employ highly skilled professional and technical expertise such as data analysis and engineering. A significant proportion of these are at the forefront of integrating data received from satellite and space based infrastructure into ground based applications.

Comparative Advantages

Australia's location in the southern hemisphere and in line with the longitude of Asia, creates advantages for Australian participation in the international space industry supply chain. It has well positioned ground stations across a 4,000 km baseline able to observe a large number of satellites, space debris and weather. It also has suitable locations for ground station calibration and validation with clear skies, low noise and low light interference. Australia is well positioned for satellite communications and control operations. Its location also gives access to a large number of satellites for Earth Observations from Space and GNSS.

Australia has a strong education system with a good research and development base in space technologies. The key challenge for the Australian space industry sector is to build a path from research to industrialising and commercialising the resulting products and services. Many Australian graduates and researchers with space capabilities leave to work overseas. It was reported that some had been attracted back but the lack of employment opportunities in the space industry sector was a key challenge for those graduates that wish to pursue a career in the space or space related sectors.

Australia's technical expertise is highly regarded by the international space community. Realising the potential of this expertise and related skills appears to be limited to a significant degree by lack of continuity of work and opportunities in the sector in Australia.

Australia's international partnerships and agreements provided an important foundation for access to the global supply chain and the development of sustainable commercial activities.

Capability weaknesses

Australia is not likely to be competitive in the manufacture of large high altitude satellites or of receivers for applications in vehicles or in positioning. However it has opportunities in the new areas of low orbit satellites and related services, design of instrumentation and sensors, design testing and manufacture of small satellites, optical communications, tracking space debris, robotics, integration of space sourced data into ground based applications, big data analysis, on board processing and launch services.

The Australian space industry has strong capabilities in many of these areas. However because of a fragmented supply chain, lack of finance or lack of baseload work, many innovations or opportunities arising out of these capabilities are not being matured, industrialised or commercialised. Many of these areas are potential growth areas in the global supply chain.

Space industry capability in Australia 1

1.1 Introduction

This report has been prepared for the Department of Industry, Innovation and Science (DIIS). The terms of reference for this work are set out in Appendix A. It was prepared before the announcement that the Commonwealth Government will establish an Australian Space Agency.

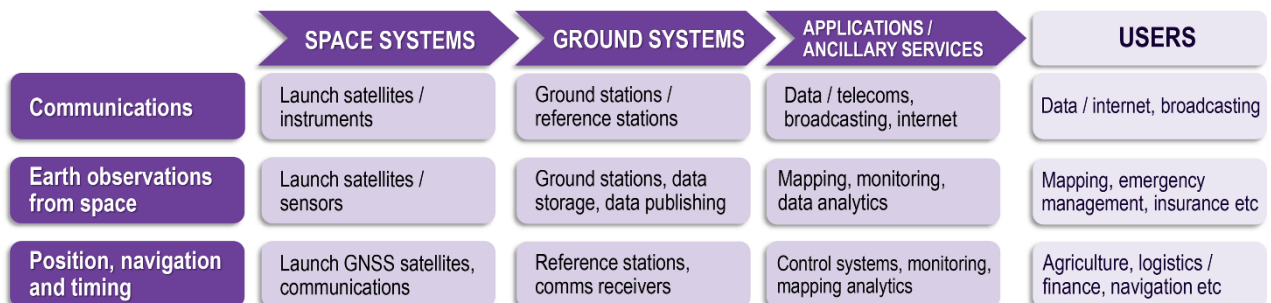
For the purposes of this report the OECD definition of the ‘space economy’ defines the broad scope of the ‘space industry’. The UK Space Agency’s interpretation of ‘space-related activity’ has been adopted as the definition of the activity carried out within a ‘space industry’ (See Appendix B for further details).

Under this approach the space industry is deemed to comprise of the following sectors:

- Space Manufacturing: Design and/or manufacture of space equipment and subsystems
- Space Operations: Launch and/or operation of satellites and/or spacecraft
- Space Applications: Applications of satellite signals and data
- Ancillary Services: Specialised support services.

An illustrative diagram of the space supply chain is shown in Figure 1.1. The supply chain is depicted in the top row, traversing space systems, ground systems, applications and ancillary services to end users. Communications, Earth Observations from Space and position, navigation and timing (PNT) are dominant areas of activity for Australia (APAC, 2015).

Figure 1.1 Space industry supply chain



Source: ACIL Allen Consulting

¹ (OECD, 2012), (London Economics, 2016)

1.2 Size of the Australian Space Industry

This report considers Australia's space capability. It focusses on areas where Australia has a commercial competitive or comparative advantage, and activities that support commercial outcomes. Government, defence and research capability are taken into account where they support, or have the potential to lead to, commercial outcomes.

The most recent industry survey (2015) found that total revenues of 46 surveyed companies amounted to \$2 billion. Noting that this was a limited survey of space industry capability, the authors estimated that the total revenue of the space industry sector in Australia was \$3 billion to \$4 billion and the sector employed around 9,500 to 11,500 staff (APAC, 2015).

On the basis of a high level review, ACIL Allen has identified at least around 388 companies (excluding legal, financial institutions and consultants), 56 education and research institutions and 24 government agencies that have space industry capability in one form or another (see Appendix C for further details). The actual number is expected to be higher than this if a thorough survey were undertaken.

It is therefore concluded that the estimate of \$3 billion to \$4 billion in revenue and around 10,000 FTEs is a reasonable estimate for the size for the space industry sector at the present time (see Appendix C).

1.3 Space industry capability

1.3.1 Space manufacturing:

Australia has very little capability in the manufacture of large satellites but Optus Satellites have developed a mature design capability for large satellites and Australia has built small satellites in the past (FedSat). Optus Satellites have designed each of their 10 communications satellites launched since 1985, including overseeing manufacture and test. Optus has also contributed to the design of the two NBN Co. satellites. Australia recently moved into the manufacture of small satellites when five universities designed and manufactured three nano-satellites for the European QB50 mission and the Buccaneer satellite for the Department of Defence. A start-up company, Fleet, has received \$5 million in Phase A funding², with an intention to manufacture 100 nano-satellites for low band width internet signals.

Australia's space manufacturing capability was enhanced with the establishment of the ANU Advanced Instrumentation and Technology Centre (AITC). The AITC was established as part of Australia's involvement in the Giant Magellan Telescope (GMT) project. It was funded to support the manufacture and test of innovative optical instruments for ground-based astronomy but the similarities between modern astronomical instrumentation and space-based systems, offered an opportunity to establish a national space environmental test facility that could support research, government and commercial projects. The facilities include a Space Simulation Chamber, Vibration and Shock, Class 10,000 Cleanrooms, Anechoic Chamber and opto-mechanical test facilities. The AITC facilities and staff can support the manufacture and test of an instrument or satellite up to 50kg and 1.5m x 1.5m x 3m. Since officially opening in mid-2014, the AITC has supported the testing of four nano-satellites and the manufacture and test of an adaptive optics system for a laser ranging telescope which was exported to KASI in South Korea under a commercial export contract managed by EOS Space Systems.

Australia has some capability in the design and development of satellite sub systems. Examples of successful companies include Small World Communications and Silanna Semiconductors who

² 11 April 2017, \$5M Phase A funding announced. Investment round led by Blackbird Ventures, including investment from Atlassian co-founder Mike Cannon-Brookes and Silicon Valley's Horizon Partners

provide components and software for international space missions. There is established research capability across all satellite sub-systems, and a growing number of start-up companies, but the maturity and value of this activity is poorly understood. The University of South Australia has developed significant capability in the development of satellite communications systems and on-board data handling and the Adelaide based company Myriota was formed in 2016 using IP generated at the university³. The Centre for Space Engineering Research (ACSER) at UNSW has developed an on-board GPS unit that was flown on their QB50 satellite and will fly on the defence tasked Biarri satellite⁴. The ANU has established research capability in plasma propulsion for satellites.

There is also well established capability in other aligned sectors that could be leveraged for space applications. The ANU has demonstrated expertise in the design and construction of high-performance optical, infrared, ultraviolet, hyperspectral and adaptive optics instruments for some of the world's leading astronomical observatories. This capability is already being applied to space debris tracking applications but it could also be applied to Earth Observations from Space. La Trobe University has an established partnership with DLR to design a hyperspectral instrument for the International Space Station with interest in further contracts. There is a growing interest in the development of optical communications systems to satisfy the demand for greater bandwidth and higher security, and to eliminate spectrum licencing issues. Australia has the existing ground-based infrastructure and capability needed to be competitive in this emerging technology area. The establishment of organisations such as the Space Environment Research Centre (SERC) and the Lockheed Martin STELaRLab, are increasing the collaboration between academia and industry and supporting these activities.

Australia has limited manufacturing capability in launch vehicles. The University of Queensland in collaboration with DST Group, has well established research capability in hypersonics. Another start-up company, Gilmour Space Technologies has received \$5 million in Phase A funding to develop low-cost hybrid rockets for small satellite launch in Australia⁵. The increased demand for nano satellite launch and the appetite for disruptive technologies is impacting this market.

Companies such as Optus Satellites, Nova Systems and SpeedCast have strong commercial capability in the design of ground stations and the ground infrastructure to support satellite communications. However, most ground stations are now assembled using modularised components provided from overseas.

There is strong capability in aligned industries such as optics and photonics, robotics, systems engineering and aviation which are essential to underpin future growth. There is also strong capability in Australia in some of the disruptive technologies such as additive manufacturing, machine learning, virtual reality and quantum cryptography⁶. In 2015, Monash University and their partners were the first in the world to print a jet engine, based on an existing engine design, resulting in spin-out company Amaero winning contracts with major aerospace companies around the world. In 2017, the team designed, printed and test-fired a rocket engine in just four months. NextAero has been established to take this technology to market. Boeing has partnered with Melbourne-based virtual reality company, Opaque Space to develop a VR training system for the Boeing CST-100 Starliner, the next generation capsule that will take people to low Earth orbit.

³ Myriota is an Adelaide based company that manufactures and markets transmitter systems for communication between ground applications and low orbit satellites. For more information visit <http://myriota.com/>.

⁴ See <https://www.dst.defence.gov.au/news/2017/04/20/biarri-satellite-heads-space>

⁵ 29 May 2017, \$5 M Phase A funding announced. Investment round led by Blackbird Ventures, including investment from 500 Start-ups.

⁶ CSIRO, 2016

Australia’s high level general space manufacturing capabilities are summarised in Table 1.1.

Maps of the supporting infrastructure are provided at Appendix D.

Table 1.1 Manufacturing capabilities

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Large satellite design, manufacture and test	Australia does not manufacture or test large satellites Mature capability in the design of communications satellites	N/A	Internationally competitive for design
Small satellite design, manufacture and test	Emerging capability in universities, start-ups and SMEs	Advanced Instrumentation and Technology Centre (AITC) Concurrent Design Facility (CDF) at UNSW Canberra	Potentially competitive but subject to financing and ability to develop scale
Instrumentation and component design and manufacture	Some examples of mature component capability within SMEs Emerging capability in universities, start-ups and SMEs Some examples of mature capability being translated to space applications	Silanna wafer and semiconductor fabrication facilities and analytics lab AITC STELaRLab Defence Innovation Hub	Internationally competitive with access to global supply chain
Laser ranging and space debris tracking telescopes	Mature capability in the design and manufacture of satellite laser ranging telescopes. Emerging capability in the manufacture of space debris tracking telescopes	satellite imagery Laser Ranging Telescopes in Canberra and WA	Internationally competitive.
Launch vehicle design, manufacture and test	No capability in heavy lift Emerging capability in hypersonics and hybrid rockets for small satellite launch	Centre for Hypersonics, University of Queensland Gilmore Space Technologies	Not competitive for manufacture Emerging competitiveness
Ground station design and installation.	Mature industry	Access to land with clear skies, low noise, spectrum access and good communications infrastructure	Internationally competitive. Southern hemisphere location highly sought after
GNSS reference station manufacture	Mature industry	Access to land with clear skies, low noise, spectrum access and good communications infrastructure	Internationally competitive
GNSS receiver manufacture	No capability		Not likely to be internationally competitive

Source: ACIL Allen Consultations, (APAC, 2015), (CATAPULT, 2014), (Defence Act, Undated), (Defence SA, 2016)

1.3.2 Space operations

Optus Satellites have more than 30 years’ experience in commercial satellite operations. They currently operate 5 Optus communication satellites and 2 NBN satellites, and have supported more than 90 international missions. There are several other commercial satellite operators, including Lockheed Martin who have a facility at Uralla in NSW, that provide telemetry, tracking and command (TT&C) services. Several Australian universities have satellite operation capability. The most notable is the Institute for Telecommunications Research (ITR) at the University of South Australia which provides commercial services as well as supporting research. The University of Tasmania operates a 26m satellite tracking antenna that is used to support commercial projects as well as radio astronomy. ANU, UNSW and University of Sydney, all have ground stations to support nano satellite missions.

Saber Astronautics has developed the Predictive Ground station Project (PIGI) software which utilises data mining and machine learning to provide operational intelligence to satellite operators. This platform is being licenced in Australia and the US. It has the potential to be customised to support the control of complex systems in other industries.

Geoscience Australia (GA), the Bureau of Meteorology (BoM) and CSIRO all have well established ground station networks and infrastructure. This capability supports Earth Observations from Space, positioning, meteorology, deep space exploration and astronomy. GA provides TT&C for Landsat 8 and downlink for Landsat 7, Landsat 8, NOAA, TERRA, AQUA, and Suomi NPP, and BoM receives data from Japanese, American, Chinese and European meteorological satellites.

The Australia Telescope National Facility (ATNF) is managed by CSIRO. The ATNF includes the Canberra Deep Space Communication Complex (CDSCC), the Parkes Radio Telescope, the Australian Square Kilometre Array Pathfinder, the Murchison Radio-astronomy Observatory (MRO), the Australia Telescope Compact Array, the Mopra Radio Telescope and the Australia Long Baseline Array. These facilities are all managed, maintained and operated by CSIRO and are staffed with Australians. Australia has developed significant capability in the command, telemetry and communication of deep space missions through the CDSCC. CDSCC is one of three NASA Deep Space Network facilities which are currently supporting more than 30 active deep space missions. CDSCC has provided critical prime receiver support for events including the Cassini End of Mission, the Mars Curiosity Landing and the Mars Phoenix Landing.

A coordinated national network of ground stations is currently being established under the Australian National Ground Segment Technical Team (ANGSTT). The ANGSTT will increase collaboration between the Australian public sector satellite operators and provide a framework for increased collaboration with international operators and the commercial sector. Such a network will support future growth in the Australian space economy.

Australia has capability in the operation of laser ranging telescopes for space situational awareness. Electro Optic Systems, an Australian listed company with global operations, manages and operates the Satellite Laser Ranging (SLR) telescope at the Mount Stromlo Observatory in Canberra and is building a second facility in Western Australia. These facilities provide automated tracking of operational satellites and space debris. Through the Space Environment Research Centre (SERC), Electro Optic Systems is developing capability in the manoeuvre of space debris for collision avoidance. Electro Optic Systems has also demonstrated an optical communications link with the Japanese Hyabusa 2.

The increase in nano satellite constellations is driving the demand for LEO launch services. Australia is geographically well positioned to support satellite launch services as it has uninhabited areas close to the equator with flight paths over the ocean. Equatorial Launch Australia (ELA) is establishing a launch complex near Gove in the Northern Territory. At 12 degrees south, this would be the second closest launch facility to the equator behind French Guiana. Launches from near the equator can deliver 20 to 40 percent more payload to orbit than from higher latitudes, as well as access to sun synchronous orbits that are highly sought after for Earth Observations from Space.

Australian industry has some capability in the operation of launch and recovery facilities. Companies such as Shoal have developed high-fidelity aerospace simulation techniques, including the Range Safety Template Toolkit in partnership with DST Group, to model the behaviour of launch, re-entry, weapon and aerospace test vehicles and support the management of vehicle risk and range safety. This expertise has been used to support the safe return to Earth of the JAXA Hyabusa capsule at Woomera and has been provided as professional services to international customers. These commercial capabilities would also be relevant to the establishment of a viable commercial launch facility elsewhere in Australia.

Australia’s geographic location has many advantages. Its large uninhabited landmass, and access to uncontrolled airspace makes it attractive for high altitude balloon launch. CSIRO manages the NASA ballooning facility at Alice Springs and the Centre National D’Etudes Spatiales (CNES) began operation in Australia in 2016. Its diverse ecosystem makes Australia perfect for calibration, validation and certification of satellite instruments. Australia is the only continent with all types of surfaces except tundra. Calibration is the centrepiece of data quality assurance and is part of the core competency of any satellite program. Calibration data obtained in the Southern Hemisphere is sparse and in demand. Validation is essential to both understand and quantify the quality and accuracy of the data products. CSIRO has a network of calibration sites and an automated calibration robot to provide these services to international customers. The Arboretum in Canberra is also being used for validation of new instruments because it has defined areas of known species.

Australia also participates in the Square Kilometre Array (SKA) project. This is a global science and engineering project developing the next generation radio telescope led by the international SKA Organisation. SKA facilities will be located in Western Australia, New Zealand and South Africa. The Australian SKA project places Australian capability at the leading edge of international competitiveness in this field.

Australia’s industry capabilities in space operations are summarised in Table 1.2

Table 1.2 Space operations

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Satellite communications	Mature commercial capability	94 Optus ground stations. 5 Optus satellites. 2 NBN Co. satellites	Competitive
	Emerging optical communications capability	satellite imagery Laser Ranging Telescope	Potential
Earth Observation and meteorology Telemetry, Tracking and Control (TT&C)	Mature commercial capability for large satellites	Ground stations sufficient to support current workload	Competitive commercial operations Competitive government operations
	Mature established government operations	National ground station network managed by ANGSTT, Australian Geoscience Digital Earth Australia, National Computational Infrastructure	
	Mature research programs	Institute for Telecommunications Research. University of Tasmania ground station. Other university ground stations.	Research stage with some commercial activity
Satellite operation software	Emerging commercial capability		Internationally competitive with access to global supply chain
Deep space TT&C	Mature capability	Canberra Deep Space Communication Complex	Internationally competitive
Telescope operation for astronomy	Mature capability	Parkes Radio Telescope, Australian Square Kilometre Array, Pathfinder, Murchison Radio-astronomy Observatory, Australia Telescope Compact Array, Mopra Radio Telescope, Australia Long Baseline Array, Pawsey Centre	Internationally competitive
Space surveillance, including satellite laser ranging, space debris tracking and space weather	Mature commercial capability for satellite laser ranging	Satellite imagery Laser Ranging Telescopes in Canberra and WA.	Competitive in niche markets and potentially in growing international markets
	Mature government capability for space weather	BoM World Data Centre for Space Weather	
	Emerging commercial capability for space debris tracking	Falcon Telescope	
	Emerging research capability		

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Launch services	Mature commercial range safety and re-entry modelling capability within Shoal		Internationally competitive with access to global supply chain
	Mature balloon launch capability	NASA Ballooning Facility	Internationally competitive
	Emerging capability for commercial launch services including plans by Equatorial Launch Services to establish launch capability in the Northern Territory	National title and state government support for launch complex	Potentially internationally competitive
Satellite calibration, validation and certification	Mature government capability	CSIRO and Geoscience Australia calibration sites, CSIRO automated calibration robot, National Arboretum	Internationally competitive location and infrastructure if it is maintained and leveraged to support access to global supply chain

Source: ACIL Allen Consultations

1.3.3 Applications

Space applications is the major strength for the Australian space industry. Sectors such as agriculture, mining, logistics, aviation and others, depend on space-derived services for communications, positioning and imagery. The integration and use of these services is enabling automation, improving land management, improving safety, and improving regional connectivity. Increasingly, space-derived data is being used by non-traditional players such as economists and insurance companies.

Satellite communications is a major area of capability in Australia. Optus and NBN Co. service a large commercial market with a total of 7 satellites in orbit, a network of ground stations and significant design and operations capability. Several smaller companies provide communications for off shore platforms, mines and other remote operations. Nova Systems, ViaSat, Northrup Grumman and Thales have a mature capability dedicated to the design and implementation of satellite communication systems for the Department of Defence. Australia has established capability within the research sector in photonics, quantum cryptography, optical design and adaptive optics that could contribute to future optical communication systems. There are many advantages to these systems including, increased bandwidth, removal of spectrum licencing limitations, and increased data security.

Earth Observations from Space is a highly developed and mature activity in Australia. Capabilities for integrating satellite imagery data into spatial applications are growing rapidly. This is being driven by demand from the Department of Defence, disaster management agencies, agriculture, vegetation mapping, ocean and atmospheric monitoring, design and development of the built environment and finance and insurance. Data from Earth Observations from Space, both imagery and synthetic aperture radar (SAR), have been used in mapping, weather modelling and forecasting, ocean monitoring, vegetation mapping, agricultural production monitoring and emergency management and are now being incorporated into 3D models of the built environment. Earth Observations from Space are also gaining application in the finance and trade sectors to monitor crop production capacity (ACIL Allen, 2015)⁷.

One of the key areas for Earth Observations from Space services is weather monitoring. The Bureau of Meteorology (BOM) provides these services on a non-commercial basis but industries such as aviation, maritime and agriculture are heavily dependent on accurate and timely weather

⁷ See also (Earth Observation Community Coordinating Group, 2016)

services. After being processed and utilised for daily services and prediction, the data is archived to support climate monitoring and disaster response. BoM has a mature weather monitoring and prediction service with 95% of its data coming from satellites. Despite not owning any of its own satellites, BoM has access to data from 20 different instruments and is highly respected in the region as a leader in satellite meteorological services and as an “honest broker”. The Bureau has developed significant capability in the development of models, simulations and applications. This capability is underpinned by a network of ground stations to receive the satellite data, a \$70 million supercomputer to store the data and the daily collection of in situ data via weather balloon and drifting buoys (ACIL Allen, 2015).

Position, Navigation and Timing (PNT) is a further area where Australian industry has established strong capabilities. Australia’s geographic location fortuitously positions it at the interface of multiple international satellite positioning constellations. This has driven the development of technologies for the integration of multiple signals for improved accuracy. This is further enhanced by the integration of augmented GNSS systems to deliver quality solutions for industry applications in logistics, navigation, agriculture, mining and transportation (ACIL Allen, 2017).

The Space Based Augmentation System (SBAS) Test bed currently underway under the oversight of the CRC for Spatial Information (CRCSI) and Geoscience Australia (GA) could create opportunities for Australian companies integrating the SBAS signal into applications in these industries across Australia. The SBAS trial is conducting world first demonstration third generation SBAS. This requires a reliable connected communications network infrastructure. SBAS Test bed project has been awarded \$12 million in Commonwealth funding.

When combined, and integrated with other data sources and technologies, satellite communications, satellite imagery and PNT can deliver high value-add products and services. The quality and impact of these products and services is dependent on access to high quality, relevant and timely data.

The development of new space applications is supported by mature research programs within Australian universities, the CSIRO and the CRCSI. There is mature capability within GA and the BoM for the development of new processes and the delivery of public good services, and there is growing expertise within Federal and State Government Departments. Landgate, NSW Spatial Services, Queensland Government and Victoria Department Environment, Land Water and Planning, are all Essential Participants in the CRCSI⁸. A 2017 ACIL Allen report prepared for the CRCSI outlines the economic value of spatial information in NSW⁹. The ACT Government identified space and spatial applications as one of their key capability areas in the 2015 Business Development Strategy¹⁰ and the South Australian Government released the Space Innovation and Growth Strategy 2016-2020¹¹. However, there is a perceived gap in the maturing, industrialising and commercialising of technologies and research activities. There are some outstanding exceptions but overall the strong research capability is not being fully exploited. The establishment of the CRCSI has had a positive impact on this issue but this gap remains a weakness.

The creation of the Digital Earth Australia concept by GA creates important opportunities for Australia. The application provides access for a wider range of users of space sourced data facilitation analysis and processing of the data into information. It is gaining recognition internationally as an opportunity for improving the application of space based data in many

⁸ CRCSI Essential Participants, Support Partners, Stakeholders and International Partners
<http://www.crcsi.com.au/partners/>

⁹ Economic Value of Spatial Information in NSW: Estimated for 2017 and 2020, ACIL Allen for the CRCSI, 2017

¹⁰ (ACT Government, 2015)

¹¹ (Defence SA, 2016)

applications. CSIRO in concert with industry is now exploring the potential for cloud based data systems similar to Digital Earth Australia for the private as well as government sector. Cloud based data access provides users with reliable, commercial access to data and analytical capabilities reducing the need for computing power. Rather than having to invest in large computer capability users can selectively purchase data and computing time from the “cloud”.

This presents a significant opportunity for Australia to leverage the expertise of its firms and position them within the global market. Digital Earth Australia is an example of infrastructure for future industries. Combined with a network of ground stations to collect the data, Australia could leverage our geographic location and existing multinational relationships to influence the specification and implementation of this infrastructure, and give Australian companies a competitive edge as early adopters. Digital Earth Australia is currently hosted by the \$50 million National Computational Infrastructure (NCI) but there are efforts to transition to a commercial cloud service to support the reliable and secure access by industry. The final component of this future infrastructure is access to a reliable high bandwidth network for the dissemination of products and services across all areas of Australia. Digital Earth Australia has been most recently provided with \$15 million in funding from the Commonwealth.

Australian expertise in space applications is internationally recognised and there are established intergovernmental relationships to provide these services. There are increasing commercial opportunities as the global space industry transitions from a government dominated industry to an industry that delivers commercial products and services that boost the productivity of other sectors. With the emergence of the Internet of Things, the use of space-derived data and services will be ubiquitous and any restriction on access will be a disadvantage.

The question of assured access to space is increasingly important as more satellites are launched. Radio frequency spectrum to transmit data and orbital slots are both finite resources. The increase in the number of satellites in orbit also leads to an increase in space debris, which leads to increased risk for satellite operators and the potential denial of service. Australia’s southern hemisphere location, large landmass, proximity to the Asia-Pacific, and existing capability in the design and manufacture of laser ranging telescopes, provides a competitive as well as a comparative advantage for delivering trusted, space debris tracking services. Future technologies being developed by the Space Environment Research Centre have the potential to contribute to the manoeuvring of space debris for collision avoidance or the removal of space debris.

Earthlight in conjunction with NASA is developing a virtual reality space application that has potential as an astronaut training system. Such examples demonstrate the innovation in small Australian start-ups. However, as discussed later, access to funding and continuity of work are important for such start-ups.

Australia’s industry capability in space applications is summarised in Table 1.3.

Table 1.3 Space applications

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Communications	Mature capability	Optus satellites, NBN satellites, ground stations	Internationally competitive
	Emerging optical communications capability	Laser ranging telescopes	Potentially competitive if successful
Earth Observation and meteorology - data storage, management, and archiving	Mature capability	Australian Geoscience Digital Earth Australia, NCI, BoM supercomputer	Data storage moving to cloud based solutions to support commercial applications
Earth Observation and meteorology - data processing and technical support	Mature capability	Australian Geoscience Digital Earth Australia, NCI, BoM supercomputer, cloud storage	Competitive in Australian context and potentially competitive internationally

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Positioning	Mature government and commercial services exist	Reference stations and beacons Internet for some services	Competitive in Australia
Third generation SBAS Augmentation service	Emerging - Test bed research underway	Reference stations and space based communications	Potentially leading edge if successful
Technical support for integration of position data into GIS, on line mapping, monitoring and control systems	Mature in parts. Emerging in other areas such as autonomous vehicles.		Emerging competitiveness
Integrated applications	Mature and strong capabilities in agriculture, weather and ocean modelling, vegetation mapping and emergency services. Emerging applications in finance, insurance and agricultural trade.	Intergovernmental relationships and agreements for data access Australian Geoscience Digital Earth Australia BoM supercomputer, NCI and cloud storage	Leading edge competitiveness
Virtual reality for space	Start-up stage		Potential opportunity for Australian Start up in partnership with NASA.

Source: ACIL Allen Consulting

1.3.4 Ancillary services

Ancillary services include technical consulting, legal, marketing and regulatory arrangements. These capabilities are well developed in the communications area where international as well as domestic markets are well developed. Insurance is less well attuned to the space industry particularly in relation to launch services where insurance costs increase significantly for launches above 1,000km. Finance for start-ups was identified as a concern where start-ups were not able to mature their technologies and applications to meet commercial criteria.

Australia’s industry capabilities in ancillary services are summarised in Table 1.4.

Table 1.4 Ancillary services

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Legal, regulatory and marketing	Well developed in communications and PNT Less well developed in satellite imagery		Niche areas of competitiveness
Finance	Patchy capabilities. Venture capital difficult to source for some SMEs partly because of need to mature technology	Industry structures in SMEs is fragmented.	Limitations in competitiveness
Insurance	Not well developed		Uncompetitive for high risk ventures such as high level launches
Education and training	Many firms and governments provide education and training		Internationally competitive

Source: (APAC, 2015) ACIL Allen Consultations

Alignment with other sectors of the Australian economy

2

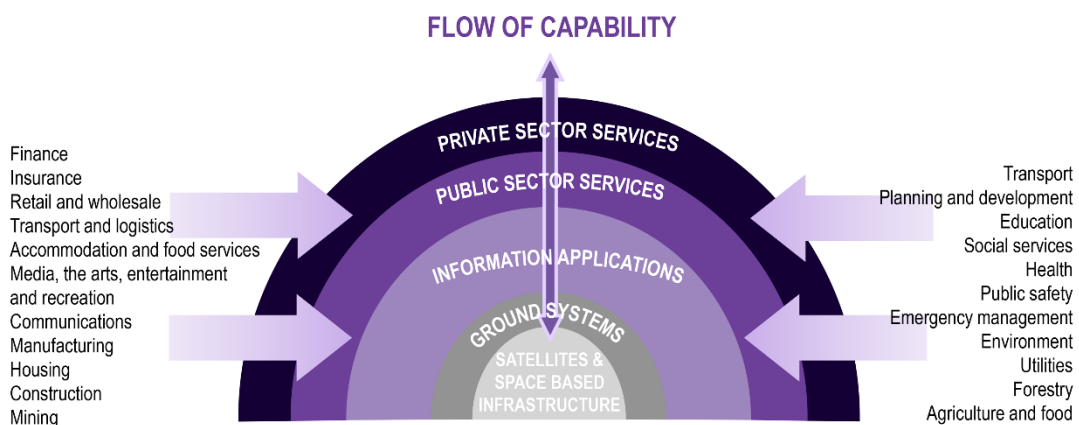
This section identifies space industry capabilities (either possessed by Australia or able to be developed) that have the greatest potential for spin-off benefits to other parts of the Australian economy.

The space industry is ubiquitous across all sectors of the Australian economy. Although considered a separate industry, the space industry, actually crosses over many industries and has long been embedded in many areas of the Australian economy both in the public and private sectors since the introduction of domestic satellite telecommunication and broadcasting services in the 1980s and more recently the advent of the internet.

Figure 2.1 below highlights the areas of the economy already using elements of the space industry in some way or other. The value to these industries and the space industry, is the information applications which is the intersection between the space industry and the rest of the economy. Capability flows both ways, from the space industry to the other sectors of the economy and from those sectors back to the space industry. The benefits of a space industry capability are embedded throughout the economy and are fluid enough to cross-pollinate and create further benefits over time.

Australia has strong capabilities that overlap with space industry capability in many industries. Industries with the highest shares of GDP including services (predominantly financial), construction, mining, manufacturing and agriculture are likely to continue to benefit from and add to space industry capability in Australia (Office of the Chief Economist, 2016). Many of these industries require highly skilled technical expertise such as data analytics or engineering, and many of these areas are at the forefront of applying spatial data received from satellite and space based infrastructure. These areas of expertise are presented in Table 2.1 below.

Figure 2.1 Cross sectoral interactions



Source: ACIL Allen Consulting

Consultations and further research into Science, Technology, Engineering and Maths (STEM) have also identified the following areas in which capability already exists (Office of the Chief Scientist, 2016) in universities, research centres (such as CSIRO’s Data61)¹², public service or the private sector that could be used in the space industry sector:

- Science: astronomy, physics, material science, weather systems and climate science, oceanography, hydrography, geology
- Technology: additive manufacturing, optics, lasers, computer science, quantum computing and machine learning, robotics and artificial intelligence
- Engineering: communications, electrical, biomedical, mechanical, civil, systems, power and agricultural engineering
- Maths: data analytics, statistics, econometrics, financial and other mathematical modelling.

Table 2.1 Overlap in capabilities and the use of space based capability already used in other industries

Major sector of the economy	Benefits from increased capability	Application of space industry capability – technology	Application of space industry capability – skills
Financial services	High	Cybersecurity, positioning	Data analytics, statistics, econometrics, financial and other mathematical modelling, systems engineering
Construction	High	Smart cities, BIM, mapping, satellite imagery, positioning	Additive manufacturing, physics, material science, communications, mechanical engineering, civil engineering, power engineering, autonomous machinery
Mining	High	Autonomous systems, mapping, satellite imagery, positioning	Material science, geology, robotics, machine learning, systems engineering, mechanical and power engineering
Manufacturing	High	Microelectronics and instrumentation (astronomy, SSA, EO); optical/SAR/hyperspectral)	Additive manufacturing, optics, lasers, machine learning, data analytics, statistics, econometrics, mechanical engineering
Agriculture	High	Autonomous systems, mapping, satellite imagery, positioning	Weather systems and climate science, hydrography, geology, robotics, agricultural engineering, data analytics
Transport	High	Applications in future intelligent transport systems	Communications, data analytics, statistics, other mathematical modelling, machine learning, control systems, autonomous vehicles, mechanical engineering, civil engineering

Source: ACIL Allen Consulting

There are six Australian industry growth centres recently identified: (i) medical technologies and pharmaceuticals; (ii) mining equipment; technology and services; (iii) oil, gas and energy resources; (iv) advanced manufacturing; (v) food and agribusiness and (vi) cyber security.¹³ These sectors have even greater potential to benefit from space industry capabilities than the existing major economic sectors. Consultations and further research have also identified the following areas which

¹² See: <https://www.csiro.au/en/News/News-releases/2017/CSIROs-Data61-delivers-for-Australia-in-its-first-year-of-operations>

¹³ See: <https://industry.gov.au/Office-of-the-Chief-Economist/Publications/AustralianIndustryReport/assets/Australian-Industry-Report-2016.pdf>

are expected to benefit from space industry capabilities. These include: smart cities¹⁴, the blue economy¹⁵ and platform development¹⁶.

¹⁴ See: <http://www.australiansmartcommunities.org.au/smart-city-transformation-2016>;
<https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/public-sector/deloitte-nl-ps-smart-cities-report.pdf>

¹⁵ See: <http://www.marinescience.net.au/blue-economy/>

¹⁶ See: <http://www.australiansmartcommunities.org.au/smart-city-transformation-2016>;
<https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/public-sector/deloitte-nl-ps-smart-cities-report.pdf>; <https://www.telstra.com.au/content/dam/tcom/business-enterprise/campaigns/smart-cities/pdfs/telstra-business-smart-cities-whitepaper.pdf>

Comparative advantages

3

The following is an evaluation of Australia's comparative advantages and how it is placed for space industry developments¹⁷.

3.1 Geography

There are a number of areas where our geography is an advantage. Australia's location in the Southern Hemisphere and at a longitude that places it conveniently in line with Asia. This has a number of advantages:

- well positioned ground stations across a 4,000 km baseline
- able to observe a large number of satellites, space debris and space weather
- suitable locations for ground stations, calibration and validation sites, with clear skies, low noise and low light interference
- suitable location for launch services with proximity to equator offering lift advantage and access to sun synchronous orbits

This places in a good position for satellite communications and control as well as providing access to a large number of satellites for both satellite imagery and for PNT. Good location for Space Situational Awareness (SSA).

3.2 Research Excellence

Australia has a strong education system with a good research and development base in space technologies. The key challenge for the Australian space industry sector is to build a path from the results of research to industrialising the concepts and commercialising the services. However, regardless of this excellence, several consults noted that many Australian graduates and researchers with space capabilities leave to work overseas¹⁸. It was reported that some had been attracted back but the lack of employment opportunities in the space industry sector was a key challenge for those graduates that wish to work in the space or space related sectors.

Australia's research capability has also been supported by government programs including the National Collaborative Research Infrastructure Strategy which included projects on astronomy,

¹⁷ Comparative advantage is typically defined as the ability to produce a product or service at a lower price. This may be determined as an opportunity cost in an international trade context. Other than lower input costs such as the cost of labour or capital, comparative advantage can be realised by a geographic locational advantage, economies of scale or more efficient internal systems. Comparative advantage does not necessarily imply that a better product or service can be produced.

¹⁸ See: <http://www.theaustralian.com.au/business/aviation/space-industrys-best-and-brightest-leaving-for-overseas-jobs/news-story/8a302e7fee26fd46336ab5a5f4bd69e9>

marine observation, geoscience and positioning, national computational infrastructure all of which have contributed to space related science in one way or another.

3.3 Technical expertise/experience

As outlined in Chapter 1, Australia has technical expertise in many important areas that support the space industry supply chain. The location of these capabilities varies across communications, satellite imagery and PNT. In some areas, such as in commercial communications satellites, that expertise is already creating commercial opportunities for technical and professional skills in Australia. In other areas the skills are located in SMEs, start-ups and universities where the extension of these skills into the commercial sphere is limited by lack of funding or continuity of work to maintain a full commercial supply chain for the outputs of research institutions.

Australian experience in Earth Observations from Space and augmentation to GNSS services positions Australian firms and institutions in a strong position compared to firms and institutions in other countries.

3.4 International partnerships and relationships

The space industry involves both government and commercial activities. Relationships between governments as well as with the government are important for success in the Australian Space Industry. Australian institutions have established relationships with all major space agencies overseas (NASA, ESA, JAXA, UK, CSA, CNES, DLR, KARI). This provides access to data and data exchange.

Agreements such as the CSIRO/ESA science and technology agreement, the GA/EU agreement, the CSIRO/NASA and CSIRO/CNES agreements, the CSIRO/UK Catapult, and relationships between primes and their parent companies can be leveraged to give access to programs and the global supply chain.

In some cases, relationships between large international companies and Australian SMEs in the space sector can constrain opportunities overseas where global marketing programs operate. Restrictions on transferring defence sensitive technologies can also limit market opportunities overseas. While this exist, overall the value of international relationships between governments and international companies is likely to be positive for Australian start-ups and research institutions in accessing global supply chains.

3.5 Challenges and opportunities for the Australian space industry sector

The importance of defence, communications, satellite imagery and PNT to the space industry in Australia combined with the comparative advantages listed above, provides a base on which Australia could build industries that turn its comparative advantage into competitive advantage¹⁹. In the long run this could be expected to build important related and supporting industries for the space sector that could be a key competitive advantage internationally²⁰.

¹⁹ Competitive advantage is an advantage over competitors gained by offering greater value, either by means of lower prices (cost advantage) or by providing greater benefits and services that justifies higher prices (differential advantage). It can also be created by creating conditions where the choice of a product is determined by the system on which it operates. What Australia has in the space industry is an ability to produce a superior offering. Differential advantage is produced by more advanced technology, patent-protected products or processes and superior capability.

²⁰ Professor Michael Porter argues that the skills developed in servicing local industry can help build related and supporting industries that are important factors in international competitiveness (Porter, 1990).

While there are early signs that research institutions and SMEs may be slowly moving down this path, there are serious obstacles along the way. For example, high costs to entry and small domestic market (lack of scale). The SME sector in the space industry is fragmented, it has difficulty finding funding for the steps necessary for commercialisation.

Scale and cost are important factors in manufacturing for the space sector. Design and manufacture of large satellites, in particular for communications and positioning, and related launch services are becoming commodities in the global space sector. There are established players in this market and the barriers to entry are high.

There are two opportunities for Australia. The emergence of smaller, more capable components and the development of standard satellite and launch platforms, are reducing the cost associated with both manufacture and launch services. This is leading to the development of low Earth orbit constellations and the development of high altitude platforms such as long duration UAVs and blimps that can target the needs of an individual company or industry sector. The second opportunity is to leverage Australia's existing instrumentation capability to design and manufacture high performance instruments to be hosted on international satellites. This is a similar approach to the aviation industry where Australia provides components as part of a global supply chain and gets access to much larger programs in return.

However there is a real issue of continuity of work. Without continuity companies face a challenge generating sufficient working capital to bring their innovations to a mature enough stage to fund and commercialise the associated products and services. (Catapult, 2014). The emergence of low earth orbit small satellites creates an opportunity for SMEs to exploit new opportunities in the space market. The lower cost of low orbit satellites and the potential for networking communications and managing large amounts of data through applications such as emerging cloud based data hubs are likely to open opportunities for SMEs working in this field.

There is significant research capability in space operations and space applications some of which is gaining important niches with larger international space companies. Lack of funding and continuity of work inhibits the potential for Australian industry to fully exploit these opportunities effectively in many cases.

There are encouraging signs that funding for innovation is emerging. The Department of Defence Innovation Hub is an important example of how government requirements can also focus on capacity building in the industry. The Next Generation Technologies Fund also represents around \$750 million over the next decade for strategic next generation technologies that have the potential to deliver new capabilities²¹. CSIRO and the CRC for Spatial Information are supporting innovation links with industry. Industry development hubs also facilitate commercialisation of new ideas from Australian universities and SMEs.

However to be successful it will be necessary for the SMEs to be able to build consistent revenue streams to be able to finance commercialisation of space based opportunities.

²¹ For further information see (Department of Defence, 2016 -1) (Department of Defence, 2016 - 2) (Department of Defence, 2016 -3).

Australian space industry capability weaknesses

4

In chapter 1 of this report the strength and weaknesses of various parts of the supply chain were discussed. This chapter focusses on weaknesses as defined in the terms of reference in the following terms:

“These weaknesses may be identified as an absence of space industry capability that is prevalent in the international market. It can also be a precursor capability that is needed to develop or grow a related space industry capability”.

There are three kinds of weakness considered in this report:

- fundamental weakness in capability – technology that is not sufficiently matured or industrialised
- structural weakness – lack of finance, scale or alliance arrangements that constrain Australian companies
- market weakness – lack of access to a market.

In assessing space industry capability weaknesses we have adopted an approach that recognises that there will be some areas where Australian space industry or research establishments have certain capabilities but for fundamental, structural or market weaknesses cannot develop them

A summary of identified weaknesses is provided in Table 4.1. A table of strengths as well as weaknesses is provided in Attachment E.

Table 4.1 Summary of weaknesses

Capability	Current status	Potential
Manufacture of large satellites	No capability	A commodity market not suited to Australian companies
Design and manufacture of small satellites	Emerging capability in universities, start-ups and SMEs	Potentially competitive but subject to financing and ability to develop scale
Instrumentation and component design and manufacture	Emerging capability in universities, start-ups and SMEs	Internationally competitive with access to global supply chain but not yet commercialised
Laser ranging and space debris tracking telescopes	Emerging capability in the manufacture of space debris tracking telescopes	Internationally competitive
Launch vehicle design, manufacture and test	No capability in heavy lift Emerging capability in hypersonics and hybrid rockets for small satellite launch	Not competitive in manufacture of heavy lift Some competitive areas subject to financing and ability to develop scale
GNSS receiver manufacture	Limited capability	Not likely to be internationally competitive
Satellite communications	Mature satellite communications industry. Emerging capability in the development of new technologies including optical systems.	Internationally competitive with regional advantage. Good potential for emerging technologies but market uncertainty for optical communication.

Capability	Current status	Potential
Satellite operation software	Emerging commercial capability	Potentially internationally competitive
Space surveillance, including satellite laser ranging, space debris tracking and space weather	Emerging commercial capability for space debris tracking	Potentially internationally competitive in niche areas
Launch services	Emerging capability for commercial launch services	Potentially internationally competitive but need a compelling strategic reason to do so
Third generation SBAS	Emerging capability subject to test bed	Potentially competitive subject to partnerships
Technical support for integration of position data into GIS, on line mapping, monitoring and control systems	Mature in parts	Emerging competitiveness

Note: Weakness does not necessary imply no capability. It could be attributable to lack of finance or regulatory constraints.

Source: ACIL Allen Consulting

Australia has leading capabilities in communications, the use and application of Earth Observations from Space and precise positioning services. There is a two way flow of technical and commercial capabilities between the space related applications and other industry sectors such as communications, agriculture, mining, vegetation monitoring, intelligent transport systems, logistics and surveying and mapping.

The table shows that the weaknesses fall in the emerging areas of low orbit satellites and related services, design of instrumentation and sensors, design, testing and manufacture of small satellites, optical communications, tracking of space debris, robotics, integration of space sourced data into ground based applications, big data analysis, on board data processing and launch services.

Australian space industry has strong capabilities in many of these areas. However because of a fragmented supply chain, lack of finance and lack of baseload work, they are not all being industrialised or commercialised. Many of these areas are potential growth areas in the global supply chain.

Appendices



This report will provide a contemporary review of Australian space industry capability, including the growth of new start-ups and the overall value to the Australian economy. It will also provide an estimate of the Australian space industry market size in terms of value, number of participants, employment and exports.

The report will:

- Identify space industry capabilities in Australia
 - describing their level of maturity (research, start-up, commercial, etc.)
 - identifying the infrastructure that underpins this capability
 - providing a comparison of the capability to competitors in the international market.
- Describe the alignment of space industry capabilities to other sectors in Australia
 - This is to identify space industry capabilities (either possessed by Australia or able to be developed) that have the greatest potential for spin-off benefits to other parts of the Australian economy.
- Identify comparative advantages in the Australian space industry sector
 - This may be because of our geographical location, technical expertise/experience, research excellence, international partnerships/relationships. The identification of a comparative advantage will be in the context how it can be exploited to grow the Australian space industry and compete internationally.
- Identify Australia's space industry capability weaknesses

These weaknesses may be identified as an absence of space industry capability that is prevalent in the international market. It can also be a precursor capability that is needed to develop or grow a related space industry capability.

Space industry definition

B

The term 'space industry' is to be defined using currently accepted/applied interpretations.

The 'OECD Handbook on Measuring the Space Economy' (2012) uses the following working definition for the 'space economy':

'The space economy is the full range of activities and use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space. Hence, it includes all public and private actors involved in developing, providing and using space-enabled products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly persuasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society.' (OECD, 2012) (OECD, 2014)

The OECD definition has been referred to in a number of subsequent reports that seek to define 'space industry'. Building on this definition, a series of reports on the UK space industry, prepared by London Economics for the UK Space Agency, has refined an understanding of the space economy/industry to identify the following as space-related activity.

A 'space-related activity' is defined to be any one (or more) of the following activities:

- Space Manufacturing: Design and/or manufacture of space equipment and subsystems
 - Including: launch vehicles and subsystems, satellites/payloads/spacecraft and subsystems, ground segment systems and equipment (control centres and telemetry), suppliers of materials and components, scientific and engineering support, fundamental and applied research.
- Space Operations: Launch and/or operation of satellites and/or spacecraft
 - Including: launch services, launch brokerage services, proprietary satellite operation (incl. sale/lease of capacity), third-party ground segment operation, ground station networks.
- Space Applications: Applications of satellite signals and data
 - Including: Direct-To-Home (DTH) broadcasting, fixed and mobile satellite communications services (incl. VSAT), location-based signal and connectivity service providers, supply of user devices and equipment, processors of satellite data, applications relying on embedded satellite signals (e.g. GPS devices and location based services) and/or data (e.g. meteorology, commercial GIS software and geospatial products).
- Ancillary Services: Specialised support services

- Including: launch and satellite insurance (incl. brokerage) services, financial and legal services, software and IT services, market research and consultancy services, business incubation and development, policymaking, regulation and oversight.

(Summary Report: The Size & Health of the UK Space Industry (December 2016))

For the purposes of the papers being prepared to support the review of Australia's space industry capability, the OECD definition of the 'space economy' will provide the broad scope of what the 'space industry' is and the UK Space Agency's interpretation of 'space-related activity' will be used as the definition of activity carried out within a 'space industry'.

Estimates of size of the industry



In this report we are focussing on organisations primarily in the private sector and in academic or research organisations that have space industry capabilities. We do not include important government institution such as Geoscience Australia, the Bureau of Meteorology or the Department of Defence as they are primarily Government. We do include parts of CSIRO and NASA that possess focussed space industry capability.

There is limited information about the value added to the Australian economy but the Australian Space Industry Sector. The most recent survey undertaken in 2015 found that total revenues of 46 surveyed companies amounted to \$2 million. The report also estimated that these companies employed 1,190 FTEs in 2015. Noting that this was a limited survey of space industry capability, the authors estimated that the total revenue of the space industry sector in Australia was of the order of \$3 to \$4 billion and the sector employed around 9, 500 to 11, 500 staff (APAC, 2015).

ACIL Allen undertook a high level review of companies, government organisations and research and education institutions that identified themselves as having space industry capabilities. This was based on information from the ‘Space Industry Association of Australia, the Spatial Industries Business Association, Defence SA, Defence ACT and internal information (Defence ACT, Undated) (Defence SA, 2016)²². The survey did not include organisations that supplied ancillary services such as legal, insurance or consulting services. On the basis of this high level research ACIL Allen identified 402 companies that had space industry capabilities, 24 government agencies with involvement in the space supply chain and 56 education or research institutions that had registered capabilities or activities relevant to the space industry supply chain. Details of these companies, government agencies and education and research institutions are provided in tables at the end of this Appendix.

In 2008 ACIL Tasman undertook analysis of the spatial information sector and estimated that at that time the spatial information industry had revenues of around \$2.5 billion (ACIL Tasman, 2008). At least around one third of these companies would have been involved in the use and application of earth observation from space and some PNT services.

This evidence confirms that the conclusion the APAC report that revenues for the space industry in Australia would have been of the order of \$3 billion to \$4 billion.

Table C.1 Space industry companies

Name	Name
3Logix Pty Ltd	IMP Printed Circuits Pty Ltd
A.W. Bell Pty Ltd	IMR Technologies
ABS Satellite	1 Spatial

²² Also referenced, (Australian Government Space Coordination Committee, 2016)

Name	Name
AAM	Indra Australia
Ace Satellite Systems	Inmarsat
Adacel Technologies Ltd	Inmarsat Solutions B.V.
Addcom Contact Solutions	Innovative Electronics Pty Ltd
Advanced Composite Structures Australia Pty Ltd. (ACS Australia)	Inovor Technologies
AECOM	Integrated Spectronics Pty Ltd
Aerometrix	Intel Australia
Aerospace and Defence Products Pty Ltd	Intelsat Asia Pty Ltd
Aerospace, Industrial and Marine Technology (AIMTEK) Pty Ltd	Intergraph Mapping and Geospatial Solutions
AFiO Group Pty Ltd	International Aerospace Law & Policy Group
Agrecon	International Aerospace Law & Practice Group
Airborne Research Australia (ARA)	International Center for Radio Astronomy Research (ICRAR)
Airbus Defence and Space	Interturbine Advanced Logistics
Airbus Group Australia Pacific	iPSTAR Australia Pty Ltd
Airwave Communications Pty Ltd	Irriscan Australia Pty Ltd
Alcatel Australia Limited	Israel Aircraft Industries Ltd (IAI)
Allied Signals Aerospace Pty Ltd	ITC Global
Almgren, J. N Pty Ltd	iVEC
Andrews Communications Systems (Delmex Pty. Ltd., trading as)	iVolve
Andromedia Industries Pty Ltd	Jacobs Sverdrup (JSA)
Anteon Australia Pty Ltd	Jeppesen Australasia
AON Space	KaComm Communications
Apogee Imaging International	Kaelus
Applied Measurement Australia Pty Ltd	KasComm Pty Ltd
Applied Satellite Technology Australia Pty Ltd	KAZ Technology Services Pty Ltd
Aria Colton Consulting	Kel Aerospace Pty Ltd
ASC Pty Ltd	Kia Consulting
Ashurst	L-3 Communications Australia Pty Ltd
Asia Pacific Aerospace Consultants (APAC)	Laboratory of Advanced Jet Propulsion Ltd.
Asia Pacific Aerospace Pty Ltd	LandStar DGPS (Thales GeoSolutions)
Asia Pacific Space Centre (APSC)	Launchbox Australia
Asteroid Enterprises PL	Leica Geosystems
Astra Australis	Locata Corporation Pty Limited
Astro Explore	Lockheed Martin Australia
Astrovision Australia	Logica Pty Limited
AU Launch Services	LSM Advanced Composites Pty Ltd
Aurega Consulting Group	Lumsden Consulting
Aurisa	M2M Connectivity
Auspace Pty Ltd	Macdonald Technologies International Pty Ltd

Name	Name
Ausplex Pty Ltd	Macquarie Communications Infrastructure Group / Broadcast Australia
AusTest Laboratories	Magellan GPS Systems
Australasian SKA Industry Cluster	MapInfo
Australasian Society of Aerospace Medicine	Maptel Pty Ltd
Australian Academy of Science	Mars Society Australia Inc
Australian Aerospace	Marsh Space Projects
Australian Aerospace & Defence Innovations Ltd (AADI)	Melbourne Space Program
Australian Industry & Defence Network Inc	Mechanica Pty Ltd
Australian Rocketry Pty Ltd	MGLSAT
Australian Technology Information Pty Ltd	Micreo Limited
AV-Comm	Minter Ellison
Axiom Precision Manufacturing	Miraxis Australasia Pty Ltd
BAE Systems Australia	Mitchell Resource Intelligence
Ball Solutions Group Pty Ltd	MITEC Ltd
Bentley Systems Incorporated	Moonshot X
Biddington Research Pty Ltd	Motorola Australia Pty Ltd
Bigmate	MPA Communications Pty Ltd
Biz Hub Australia	Mullard Space Science Laboratory, Australia (UCL)
Boeing Australia Ltd	Murdoch University
Brenco Aerospace Pty Ltd	Myriota Pty Ltd
Broens Industries Pty Ltd	Navigate Pty Ltd
Bronron Apps	NBNCo Limited
Bruxin Pty Ltd	Neumann Space
C & L Aerospace Pty Ltd	NGIS
Calsa Pty Ltd	NextAero
Cansyd Australia Pty Ltd	Nodesat
Capital Technic Group	Nortel Networks Australia Pty Ltd
Cardno Lawson Treloar Pty Ltd	Northrop Grumman
CB Aerospace	Nova Systems Pty Ltd
CEA Technologies Pty Ltd	Obelisk Systems
Ceanet Pty Ltd	OmniSTAR Pty Ltd
CES Computers Pty Ltd	Omnalink
CGI	One Giant Leap
Cingulan Pty Ltd	Opaque Space
Cisco Systems Inc.	Optus Satellite Services (Singtel Optus Pty Limited)
Clearbox Systems	Oracle Corporation Australia
Cobham Aviation Services	Orbis Technology
Codan Pty Ltd	Orbit Australia Pty Ltd
Codarra Advanced Systems Pty Ltd	Otus Intel

Name	Name
Compliance Engineering	Outora
Compucat Research Pty Ltd	Ovass
Consult Australia	Ozius Spatial
Cooper Grace and Ward	OzQube-1
Coutts Communications	Pacific Satellite Pty Ltd
Cray Inc	Pegasus Aeromedical Consulting
Crown Lands Division (NSW)	Peregrine Semi-Conductor Australia (PSA)
Crystal Forrester	Picosat Systems
CSC Australia Pty Ltd	Pivotel Satellite Services
Cygnus Satellite	PlusComms Pty Ltd
CTF Solutions	Pod Trackers ANZ Pty Ltd
Cuberider	Position and Navigation Systems Pty Ltd
Curiosat	Position One Consulting Pty Ltd
Cubic Defence Australia Pty Ltd	Position Partners
Customs Agency Services Pty Ltd	Precision Agriculture
Cygnus Satellite/URSYS	Proximity
Cypher Research Laboratories Pty Ltd	Precision Pastoral Pty Ltd
Cypher-Howe Associates	Price Waterhouse Coopers
Daronmont Technologies Pty Ltd	Project Thunderstruck
Deacon Communications	Provideo
Delta-V Space Alliance	Pynfall Pty Ltd
Dialog Pty Ltd	QinietiQ
Digital Globe International	Radarsat International
Dronemetrex	Raytheon Australia Pty Ltd
EADS Australia Pacific Pty Ltd	RGR Laser (Formally Applied Laser Pty Ltd)
Earthinsite.com Pty Ltd	Red Hat Asia Pacific
Earthspace	Relken Engineering
eB2Bcom Pty Ltd	ResearchSat
EBA Solutions	RLM Systems Pty Limited
EBSCO Australia	Rohde and Schwarz (Australia) Pty Ltd
Ebsworth & Ebsworth	Rosebank Engineering Australia
Ecology and Heritage Partners Pty Ltd	RPS Group Plc
Economic Futures Australia	Rutex
Electro Optical Space Systems Pty Ltd	Ryan Faulkner
Elementrex	SA Satellite
EM Solutions	Saab Systems Pty Ltd
Embedded Pty Ltd	Saber Astronautics Australia Pty Ltd
EMS Global Tracking	Sach Initiatives
Engineering and Scientific Systems Pty Ltd (ESS)	Seaskip Pty Ltd
Environmental Systems and Services	Schweizer Kobras

Name	Name
Equatorial Launch Australia Pty Ltd	SES World Skies
ER Mapper	SGI Australia
Ericsson Defense Systems	Shoal Group Pty Ltd
ESRI Australia Pty Ltd	Siemens Pty Ltd
ESS Weathertech	Silanna Semiconductor
ETP Pty Ltd	Silicon Cocoon Pty Ltd
EWA Australia Pty Ltd	Sirion Global
Farmscan AG Pty Ltd	SkyKraft Pty Ltd
Fast Networks	Sky and Space Global Limited
Fleet Space Technologies	Skybridge Group Pty Ltd
Flurosat Pty Ltd	Small World Communications
Forge Holdings Pty Ltd	SMS Consulting Group Limited
Foxtel Management Pty Ltd	Soliton Network Consulting
Frazer-Nash Consultancy Limited	Southern Cross Space and Communications Pty Ltd
Fugro Spatial Solutions Pty Ltd	Space Adventures Ltd (USA)
Fullarton Space Biotech Co. Ltd	Space Images Tasmania
Futron Corporation	Space Qualified Ltd
Future Fleet Pty Ltd	Space-Industry.com
Future Materials	Spaceguard Pty Ltd
Gap Geo Pty Ltd	Spacelink Consulting
GenaWare Pty Limited	SpaceOps
General Dynamics Media Ware	Spaceport Australia
Geo Digital Pty Ltd	Spatial Industries Business Association
Geo Mapping Technologies	Spatial Vision
Geo-Maps Co	Spatial Sciences Institute
Geoarc Consulting Pty Ltd	Spatial Solutions
Geocode Mapping and Analysis P/L	SpecTerra Services Pty Ltd
Geodata Information Systems	SpeedCast Ltd
Geodex Pty Ltd	Station Innovation
Geoimage Pty Ltd	Stavros Georgiadis
Geological Society of Australia	STEM Network
Geomatic Technologies Pty Ltd	STEP Electronics
Geomet Pty Ltd	Strategic Effects
Geoplex Pty Ltd	Sun Microsystems Australia
Georeality	Swedish Space Corporation Australia
Geoscience Australia	SYPAQ
GeoSmart Ltd	Tait Electronics
Geospatial Applications Solutions Pty Ltd	Takor Group
Geospatial Intelligence Pty Ltd	Talk Satellite
Geospectrum Pty Ltd	TC Communications

Name	Name
Gilat Australia	Teakle Composites
Gilmour Space Technologies	Technical and Field Survey Pty Ltd
GKN Aerospace Engineering Services	Technik Group
Global Innovation Centre Pty Ltd	Technology Industry Association SA
Global Vision Network	Telecommunications Association Inc (TelSoc)
Globecast Australia Pty Ltd	Telstra Corporation Limited
Gps Solutions	Tenix Defence Pty Ltd
GPS-Ag	Terranean Mapping Technologies Pty Ltd
GPSat Systems Australia Pty Ltd.	Tetradcom
Greenhouse Gas Monitor Australia Pty Ltd	Thales Australia
Grollo Aerospace Pty Ltd	Think N Tinker Pty Ltd
Groundprobe Pty Ltd	Tidetech Commercial Marine Pty Ltd
Hartec Ltd	Toolcraft Precision Engineering
Hawker de Havilland Pty Ltd	Topcon Precision Agriculture
Hawker Pacific Pty Ltd	TR Corporation
Heliaq Advanced Engineering	Transfield Pty Ltd
HEO Robotics	Transponder Technologies Pty Ltd
Hewlett Packard Australia	Trimble NavigationAustralia
Hexigeo	TRS Engineered Solutions
Hexagon Geospatial	Ubiquitous Solutions
Honeywell Limited (pacific)	Unisys Australia Limited
HP Invent	V-Com
HTM Pty Ltd	Verizon Enterprises
Huawei Australia Pty Ltd	Viasat
Huck Australia Pty Ltd	Virtual Reality Astronaut Training
Hugh Carrigg Aerospace	Vipac Engineers and Scientists Ltd
Hydrix	Visual Analysis
Here	Vision Uplink Australia Pty Ltd
Hypercubes	Visionstream Pty Ltd
HyVista	VRT Systems
IBM Australia Ltd	Webmap Pty Ltd
ICIA consultants	Weebill Space
iMove CRC	

Source: Space Industry Association of Australia, Spatial Information Business Association, (Defence SA, 2016) (Defence ACT, Undated)

Table C.2 Education and research institutions that report involvement in space activities and capabilities

Name	Name
Australian Geospatial Intelligence Organisation	Department of Defence - Defence Space Directorate
Adelaide Planetarium	Department of Defence - Military Law Centre
Australian Astronomical Observatory (AAO)	Department of Defence – Space Operations
Australian Square Kilometre Array Office	Landgate (WA)
Bureau of Meteorology - IPS Radio and Space Services	Space Licensing and Safety Office (SLASO)
Canberra Deep Space Communication Complex - Tidbinbilla	Swinburne University of Technology
Defence ACT	Sydney Aerospace & Defence Interest Group
Defence Industries Queensland	Sydney Aerospace and Defence Interest Group
Defence SA	The Australian Centre for Remote Sensing (ACRES)
Defence Science and Technology Group	The University of Adelaide - Centre for Defence Communications and Information Networking
Defence Teaming Centre (DTC)	WA Remote Sensing Industry Development and Education Centre (WARSIDEC)
Department of Defence - Capability, Acquisition and Sustainment Group	WA Science and Technology and Application Consortium (WASTAC)
Department of Defence - Defence Space Coordinating Office	

Source: Space Industry Association of Australia, Spatial Information Business Association, (Defence Sa, 2016) (Defence Act, Undated)

Table C.3 Education and research institutions that report involvement in space activities and capabilities

Name	Name
Academic Space Launch Initiative	The University of Adelaide - School of Mechanical Engineering
Australian National University - Advanced Instrumentation Technology Centre	The University of Melbourne
Australian National University - Giant Magellan Telescope	The University of Queensland - Biophysical Remote Sensing Group [incl. Joint Remote Sensing Research Program]
Australian Space Research Institute Ltd (ASRI)	The University of Queensland - Centre for Hypersonics
Australian Telecommunications CRC (ATCRC)	The University of Sydney - Spacenet
Central Queensland University	University College London
Centre for Australian Space Education (CASE)	University of Adelaide
Charles Darwin University	University of Ballarat
Charles Sturt University	University of Canberra
Cooperative Research Centre for Satellite Systems (CRCSS)	University of New England
Cooperative Research Centre for Space Environment Management	University of New South Wales - Australian Centre for Astrobiology
Cooperative Research Centre for Spatial Information (CRCSI)	University of New South Wales - Australian Centre for Space Engineering Research (ACSER)
CSIRO - Astronomy and Space Science	University of New South Wales - Bluesat Project
Curtin University	University of New South Wales - Canberra (ADFA)
Edith Cowan University	University of New South Wales - Department of Astrophysics and Optics
Flinders University	University of New South Wales - Laboratory for Student Space Development

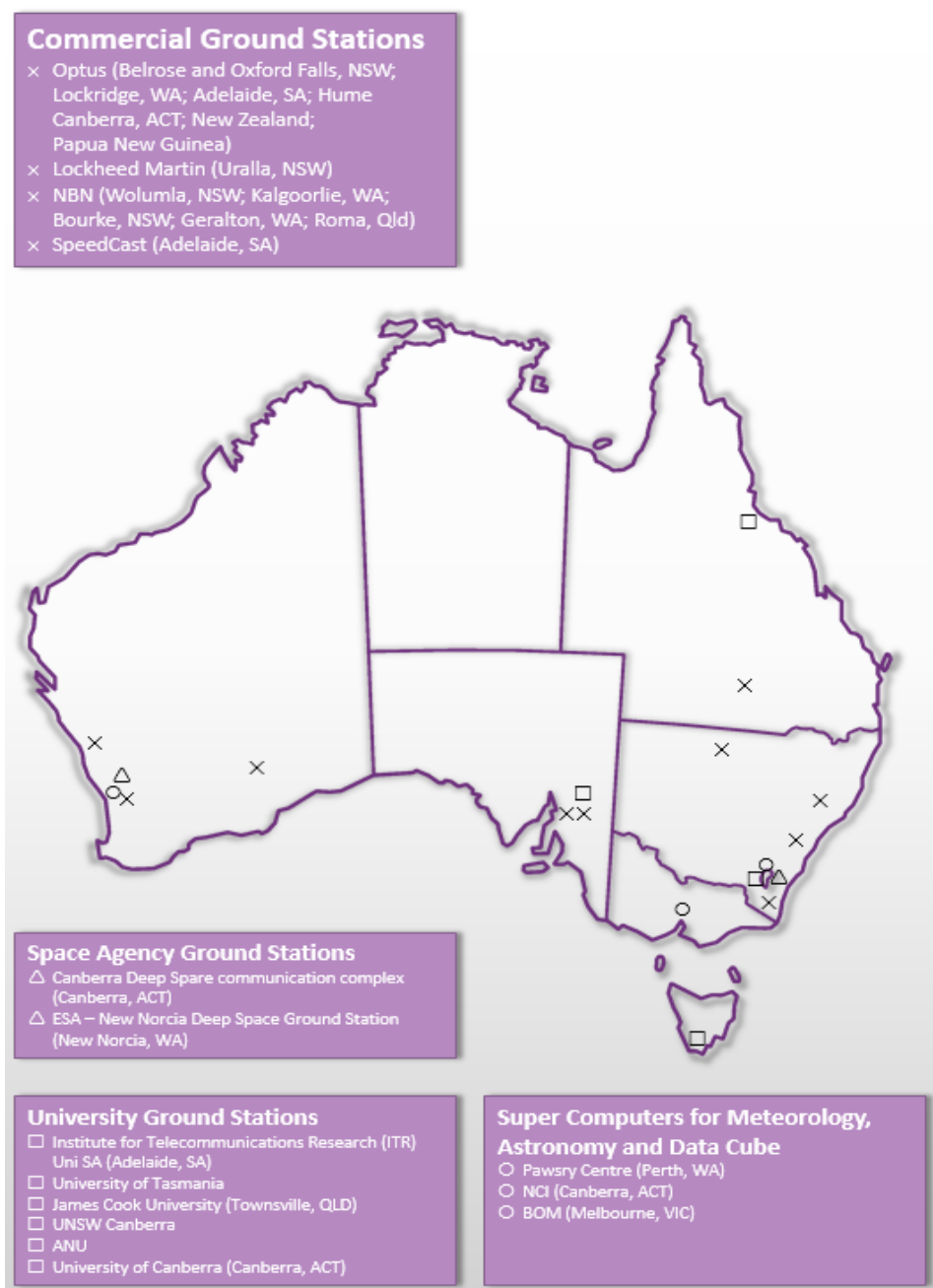
Name	Name
La Trobe University	University of Newcastle - Centre for Space Physics
Macquarie University	University of South Australia - Ian Wark Research Institute
Monash University	University of South Australia - Institute for Telecommunications Research (ITR)
Queensland University of Technology	University of South Australia (UniSA)
Queensland University of Technology - Australian Research Centre for Aerospace Automation (ARCAA)	University of Southern Queensland
Queensland University of Technology (Faculty of Built Environment and Engineering)	University of Tasmania
RMIT Space Technology Association	University of Technology Sydney
South Australian Space School	University of Western Australia
Southern Cross University	University of Western Sydney
Southern Hemisphere Space Studies Program (ISU/UniSA)	University of Wollongong
Space Environment Research Centre	Victoria University
The University of Adelaide	Victorian Space Science Education Centre (VSSEC)

Source: Space Industry Association of Australia, Spatial Information Business Association, (Defence SA, 2016) (Defence ACT, Undated)

Space infrastructure locations

D

Figure D.1 Non-government ground stations



Source: ACIL Allen Consultations with Industry and Government

Figure D.2 Related capabilities



Source: ACIL Allen Consultations with Industry and Government

Figure D.3 Australian Government ground station network



Legend

- Operational Tier 1/2 coverage
- Operational Tier 3/4 coverage
- Proposed Tier 1/2 coverage
- Proposed Tier 3/4 coverage
- Ground Station
- Australian maritime jurisdiction

Source: ACIL Allen Consultations with Industry and Government

Australian space industry capabilities – strengths and weaknesses



This appendix lists out the capabilities in terms of strengths and weaknesses. The terms of reference for this report included a requirement to identify Australia’s space industry capability weaknesses. Weakness in this case was defined in the terms of reference as:

“These weaknesses may be identified as an absence of space industry capability that is prevalent in the international market. It can also be a precursor capability that is needed to develop or grow a related space industry capability”.

There are three kinds of weakness considered in this report:

- fundamental weakness in capability
- structural weakness – lack of finance, scale or alliance arrangements that constrain Australian companies
- market weakness – lack of access to a market.

A summary of strengths and weakness is shown in Table E.1.

Table E.1 Summary of strengths and weaknesses

Capability	Current status	Potential	Strength/weakness
Manufacture of large satellites	No capability	A commodity market not suited to Australian companies	Fundamental weakness in competitive advantage
Small satellite design, manufacture and test	Emerging capability in universities, start-ups and SMEs	Potentially competitive but subject to financing and ability to develop scale	Potential but structural weakness
Instrumentation and component design and manufacture	Emerging capability in universities, start-ups and SMEs	Internationally competitive with access to global supply chain but not yet commercialised	Structural weakness
Laser ranging and space debris tracking telescopes	Emerging capability in the manufacture of space debris tracking telescopes	Potential opportunities	Internationally competitive
Launch vehicle design, manufacture and test	No capability in heavy lift Emerging capability in hypersonics and hybrid rockets for small satellite launch	Commodity service Not an obvious area of potential	Fundamental weakness in manufacture of heavy lift Some competitive areas subject to financing and ability to develop scale
Ground station design and installation.	Mature industry	Access to land with clear skies, low noise, spectrum access and good communications infrastructure	Internationally competitive. Southern hemisphere location highly sought after
GNSS reference station manufacture	Mature industry	Access to land with clear skies, low noise, spectrum access and good communications infrastructure	Internationally competitive

Capability	Current status	Potential	Strength/weakness
GNSS receiver manufacture	Limited capability	Limited potential	Fundamental weakness. Not likely to be internationally competitive
Satellite communications	Mature commercial capability	Some potential to expand market Potential	Competitive
	Emerging optical communications capability		Emerging
Earth Observation and meteorology Telemetry, Tracking and Control (TT&C)	Mature commercial capability for large satellites	Potential to grow services	Competitive
	Mature established government operations		Research stage with some commercial activity
	Mature research programs		
Satellite operation software	Emerging commercial capability	Some potential to develop the market	Internationally competitive in selected areas
Deep space TT&C	Mature capability	Established market	Competitive
Telescope operation for astronomy	Mature capability	Established market	Competitive
Space surveillance, including satellite laser ranging, space debris tracking and space weather	Emerging commercial capability for space debris tracking	Potential in niche markets	Potentially competitive
Launch services	Emerging capability for commercial launch services	Potentially internationally competitive but need a compelling strategic reason to do so	Potentially competitive
Satellite calibration, validation and certification	Mature government capability	Potential	Internationally competitive location
Earth Observation and meteorology - data storage, management, and archiving	Mature capability	Potential to export Digital Earth Australia concepts. Existing and potential private sector activity	Competitive
Earth Observation and meteorology - data processing and technical support	Mature capability	Potential to expand	Competitive in Australia
Positioning	Mature government and commercial services exist	Strong potential in Australia	Highly competitive in Australia
Third generation SBAS	Emerging capability subject to test bed	Potentially competitive subject to partnerships	Leading edge competitive if successful
Technical support for integration of position data into GIS, on line mapping, monitoring and control systems	Mature in parts	Emerging potential	Emerging competitiveness
Integrated applications	Mature and strong capabilities in agriculture, weather and ocean modelling, vegetation mapping and emergency services.	Significant potential	Highly competitive
	Emerging applications in finance, insurance and agricultural trade.		
Virtual reality for space	Start-up stage	Potential in niche markets	Potentially competitive
Legal, regulatory and marketing	Well developed in communications and PNT	Not a significant area of potential	Competitive in niche areas but generally not competitive
	Less well developed in satellite imagery		
Finance and insurance	Patchy capabilities. Venture capital difficult to source	An area of weakness	Not competitive

Capability	Current status	Potential	Strength/weakness
Education and training	Many firms and governments provide educating and training	Strong capabilities and potential	Market weakness limits opportunities in Australia

Note: Weakness includes any absence of capability including capabilities that cannot be financed for one reason or another

Source: ACIL Allen Consulting



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