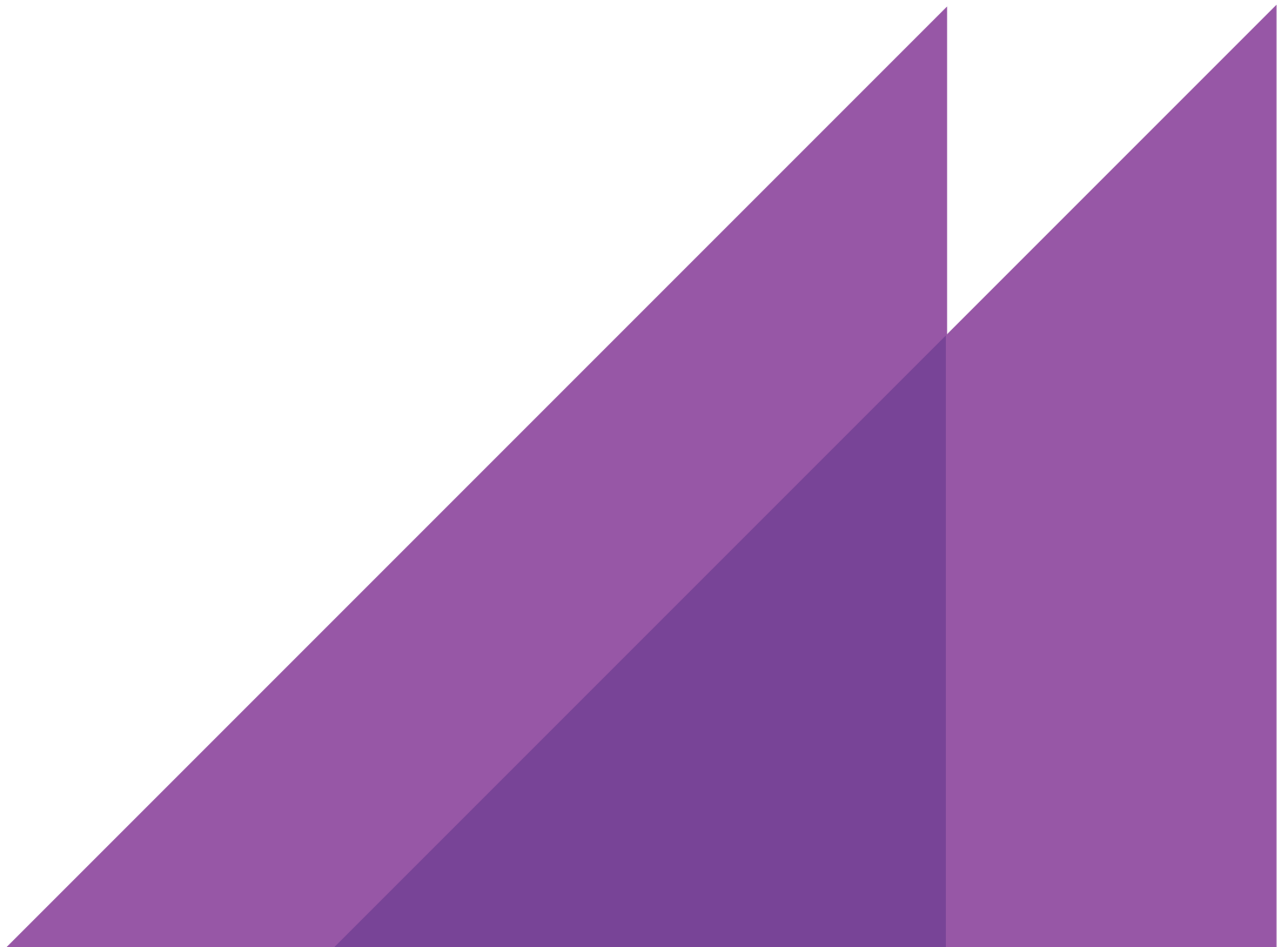


REPORT TO
THE DEPARTMENT OF JOBS, TOURISM, SCIENCE AND INNOVATION
21 MAY 2018

SPACE INDUSTRY CAPABILITY IN WESTERN AUSTRALIA



A REVIEW





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KEY POINTS

- Western Australia's southern hemisphere location and longitude are ideal for space situational awareness and facilities that contribute to global coverage of space assets, including tracking of launches. They also provide maximum access to Global Navigational Satellite System (GNSS) constellations.
- These geographic advantages have been reinforced by investments in communications and computational infrastructure and access to technical expertise. They create significant opportunities for space situational awareness, optical communications, astronomy, space operations and defence space applications.
- There are substantial capabilities in remote operations of space systems and ground stations in Western Australia and established training programs that could be adapted to support growth in these areas.
- Western Australian also hosts capabilities in development and use of space-derived applications. Opportunities for competitive advantage lie in agriculture, mining, offshore oil and gas, remote operations and robotics. The greatest potential for economic growth and jobs is likely to be found in these areas. They deserve some priority in this respect.
- Issues to be addressed include:
 - raising the profile of the strengths of the Western Australian space industry sector nationally and internationally
 - strengthening existing space operations capacity
 - developing the priority areas
 - increased collaboration on research development and innovation
 - reviewing the adequacy of professional and technical education to support Western Australian priorities.



EXECUTIVE SUMMARY

Introduction

The space industry in Western Australia is characterised by a cluster of facilities and institutions supporting space missions and space operations, strong research programs in the four universities focussing on space activities and applications, and around 98 international and Australian companies operating in space and space related services of which 74 are understood to have a presence in Western Australia.

There is no data on the economic contribution of the space industry available for Western Australia. However, a study by ACIL Tasman completed in 2008 estimated that the value of the spatial industry to Australia was between \$6 billion and \$12 billion. While this study provides only a general indication of the value to Australia of space related activities the magnitude of the impacts nationwide suggests that the impacts in Western Australia are also significant given the importance of spatial and space related data and services to most of Western Australia's major industries as well as to government services.

Capability review

Manufacturing

The most significant manufacturing activity in Western Australia relates to the installation and maintenance of ground infrastructure. This includes ground stations for deep space communication, Earth Observation, radio astronomy, satellite laser ranging, situational awareness and radio-quiet power systems.

Other areas of research, design or manufacturing in Western Australia are associated with development of electronic systems for mobile defence satellite communications, development and testing of ground-based instruments, design and manufacture of advanced electronic systems for remote operation of radio astronomy telescopes and receivers, network systems, remote sensing and remote operations for robotics and autonomous vehicles operating in hostile environments. There is potential for development of capabilities in space-based sensors, control systems and robotics.

There is no capability in launch facilities or design and manufacture of large satellites. There is some research and development in design and manufacture of small satellite systems, but it appears to be at a very early stage of development.

Operations

Western Australia has mature industry capabilities in the maintenance and operation of ground-based space systems, often in remote and harsh environments. This includes operations in: astronomy; deep

space communications; satellite communications; earth observations from space; space situational awareness; telemetry, tracking and control; and defence communications.

These activities include operation of ground station facilities clustered around communications infrastructure provided by AARNet and Defence. They employ highly trained professionals and technicians providing a small base of technical capability for space support services. There is also significant computational capability at the Pawsey Supercomputing Centre located in Perth. Neither the Pawsey centre nor AARNet are available for commercial applications.

Western Australia's geographic location in the southern hemisphere is particularly suited to the siting of ground stations supporting a wide range of civil and defence applications. There is an opportunity to attract more ground station operators to Western Australia, through the availability of relevant communications and related infrastructure and a skilled workforce. While infrastructure is a strength, there is also a risk that could support remote operation from the east coast, or an international location for that matter. This risk might be mitigated through development of an ecosystem around the collation and timely use of data and access to a highly skilled local workforce.

SSC Space Australia reported no plans to expand its operations at the Western Australian Space Centre at this time. The European Space Agency has expressed interest in expanding its deep space tracking families at New Norcia. NASA is in collaboration with Woodside in the trialling and testing of robotics and would be aware of Western Australia's capabilities.

Applications

Applications of space sourced data and services offer the most opportunities for growth and jobs. There are many activities in the private and public sectors utilising satellite communications, position navigation and timing (PNT), Earth Observations from Space and data analytics. The main areas where Western Australian companies are likely to be able to develop unique capabilities are in defence, agriculture, mining and offshore petroleum production.

The 2016 Defence White Paper foreshadows continuing investment in space-based and space-enabled capabilities. This creates opportunities in Western Australia in applications such as the Desert Fireball Network (DFN) and defence satellite communications.

Agriculture is a major user of applications in precision farming and Western Australian wheat farmers have been early adopters. There are many applications developed in Western Australia to meet these needs such as Pastures from Space developed originally by Landgate. Agriculture is moving into the digital age drawing on positioning, autonomous vehicles and drones, variable rate fertiliser application, yield monitoring, animal location and behaviour monitoring, and vegetation mapping. In the longer term it will move to the use of data analytics to improve farm enterprise decision making. A recent study by the Australian Farm Institute estimated that digital agriculture could increase the value of agricultural production by around 25 per cent.

Western Australian mining companies are world leaders in the use of autonomous mining vehicles and have been active in developing robotic mining. The mining sector draws on space-based data for many applications including vegetation and remediation mapping, positioning and guidance for autonomous vehicles as well as for compliance with the terms of their operating licence.

Offshore petroleum operations are critically dependent on space sourced data including augmented GNSS, satellite imagery and communications for rig positioning, shallow water bathymetry, ocean and weather monitoring, vessel navigation and emergency management. The offshore sector is highly data intensive with some operations reported to collect data from over 800 sensors.

The joint work by Woodside and NASA in trialling remotely operated vehicles and machinery is an example of the potential for Western Australia's industry and research institutions to move to the forefront of robotics and remote operations.

Two demonstration projects are being conducted in Western Australia as part of a national pilot project to test an advanced Space Based Augmentation System. Such systems have the potential to improve the accuracy and safety of autonomous systems and would be highly relevant to the mining and agricultural sectors in Western Australia.

Space applications are also applied in other areas of government and industry including emergency services, vegetation mapping, logistics and transport, construction, land management and finance and insurance. There are many applications that have been successfully developed by Western Australian based firms.

Auxiliary services

Western Australian firms and research institutions have developed capabilities and skills in technical consulting, space law and space policy, and planning and construction in remote areas. Technical and professional training are also strengths that support space related activities and applications.

Alignment with other sectors

Data from, and activities of, the space industry are embedded in many sectors of the Western Australian economy just as they are elsewhere in Australia. The situation in Western Australia differs in three ways from that of Australia generally.

First, the Western Australian economy has three important industries: agriculture, mining and offshore oil and gas. This generally provides firms supplying these sectors with experience and an edge over other firms in Australia.

Second, the existence of significant activity in astronomy, space operations, and positioning activity creates a further focus for science and research in Western Australia. This has established important technical expertise in areas such as data analytics, microelectronics, radio frequency interference, sensors, remote operations, autonomous vehicles and robotics.

Third, there are important defence requirements that are closely linked to the space sector which generate demand for space-based applications.

Comparative and competitive advantage

Western Australia has important comparative advantages that create opportunities for the space industry. It is a good location for ground stations, radio telescopes and satellite laser ranging telescopes because its geographic location, extensive radio quiet zones and experience operating in remote and often harsh environments. This experience is supported by good communications and computational infrastructure.

Western Australia's southern hemisphere location and longitude are ideal for space situational awareness and networks that require global coverage of space assets, including tracking of launches. Its location also provides maximum access to Global Navigational Satellite System (GNSS) constellations.

ACIL Allen identified 91 firms operating in the space industry and related sectors of which 67 had a presence in Western Australia and 55 were Australian based. The firms vary from small and medium enterprises to global companies.

The strength of the agricultural, mining and offshore oil and gas industries and their demand for advanced space and spatial services provides an ideal environment for Western Australian companies to build competitive advantage in servicing these areas. Other areas that use space and spatial services are important, but it is in the first three areas where Western Australian companies can build a competitive advantage.

Opportunities for growth in industry and jobs

The space science sector, as represented by the research institutions and universities, is an important foundation activity that generates capabilities in electronics, communications and installation of space facilities and infrastructure. In parallel, space industry activities in communications, space situational awareness and defence benefit from Western Australia's geographic comparative advantages. These activities have the potential to grow in Western Australia, but they are not likely to be the greatest source of economic growth or jobs.

The greatest potential for economic growth and jobs is in the applications area and, in particular, those areas that provide services to agriculture, mining and offshore oil and gas operations. This is where Western Australian organisations are most likely to be able to develop a competitive advantage.

Firms servicing other sectors, such as emergency services, construction and logistics also have growth potential, but are less likely to enjoy a competitive advantage compared to firms elsewhere in Australia.

Space operations, astronomy and research sectors are important to the overall competitive framework. They provide the focus for a sovereign space capability that has the potential to bring international players to Western Australia; building international as well as national collaboration. This reinforces space sector capabilities and strengthens the scope for technology transfer with Western Australian firms, especially those servicing defence, agriculture, mining and offshore petroleum.

Issues and recommendations

Raising the profile of the WA space industry sector

Government should raise the profile of the State's strengths in space science, operations and applications particularly in agriculture, mining and robotics. This could commence with discussions with the Australian Space Agency, when established, but should also include engagement with national and international agencies and relevant industry organisations.

The Government should consider the possibility of joining the existing collaboration between South Australia, the ACT and the Northern Territory to promote coordination and cooperation of the different competitive strengths.

Strengthening existing capacity

Western Australia should leverage its geographic advantage by strengthening infrastructure and building capability in areas such as GNSS, Earth Observation, optical communication, deep space tracking and space situational awareness.

Western Australia should build on the investment in research infrastructure such as the Pawsey Centre and AARNet. The case for making these facilities accessible to industry for commercial applications should be evaluated. Establishing commercial operational procedures and broadband connectivity for companies should be considered.

The Western Australian Government should evaluate opportunities for investment in technical facilities that will stimulate commercial activities in Western Australia, such as compliance testing for the SKA, with a view to these facilities establishing a capability to support other commercial projects.

Opportunities for operating and/or running space infrastructure in Western Australia should, where feasible, be offered to the private sector to help local industry develop and grow its business base around space industry activities.

Develop priority areas

The competitive strengths of the space industry and applications sector in remote operations of sophisticated systems should be supported by aligning the activities of government, industry, research institutions and research funding.

Government and industry should build on existing capability and international relationships and seek projects that will establish capability in Western Australia and support technology and knowledge transfer consistent with Western Australian priorities.

Government should review the availability and adequacy of funding to the private sector for pre-competitive research, development and demonstration of applications, with emphasis on those servicing agriculture, mining, offshore operations and remote operations and robotics.

Collaboration

There is a divergence between the business models for research into space science conducted by universities and space agencies, and research undertaken for development of commercial products and services by companies. Government should investigate the effectiveness of collaboration between the research institutions and industry, including the effectiveness of existing collaborative

arrangements, with a view to improving the development of new products and services by the private sector in Western Australia.

Noting that Western Australian institutions and companies already have expertise in cyber security and space situational awareness, the Western Australian Government should encourage increased collaboration between civil and defense space activities.

Education

The adequacy of existing professional and technical training programs should be reviewed against the needs of the space industry and the applications areas particularly with respect to the priority areas of competitive advantage identified in this report.



This report has been prepared for the Department of Jobs, Tourism, Science and Innovation. The terms of reference are to report on the following matters:

1. Existing space industry capability in Western Australia by category as established by the OECD and refined by the UK Space Agency (see Attachment 1).
2. Alignment with other sectors including defence, cyber security, geospatial data acquisition and management, 'big data' processing, automation and remote/hazardous operations.
3. Western Australia's comparative and competitive advantages including geography, research, technical capabilities and existing partnerships and relationships.
4. Opportunities for growth in industry, jobs, the research sector and training to support development of a sovereign space capability.

The report was based on research and consultations with 43 stakeholders of which 13 were in government/ research/ education, 6 were in collaboration organisations and 24 were in the private sector. The list of organisations interviewed is provided at Appendix D.

The report has been prepared against the background of the Review of Australian Space Industry Capability chaired by Dr Megan Clark AC and the Australian Government's announcement in September 2017 to establish an Australian Space Agency.

1.1 Definition of the Space Industry in Australia

This report adopts a definition of the space industry that is based on the OECD definition of the space economy and is refined by a definition of the space industry developed in a series of reports prepared for the UK Space Agency. As this report found, the space industry includes not just the direct space sector but also includes space derived products, services and knowledge on economy and society.

For the purposes of this report we have adopted the following definition of the space industry:

- 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.

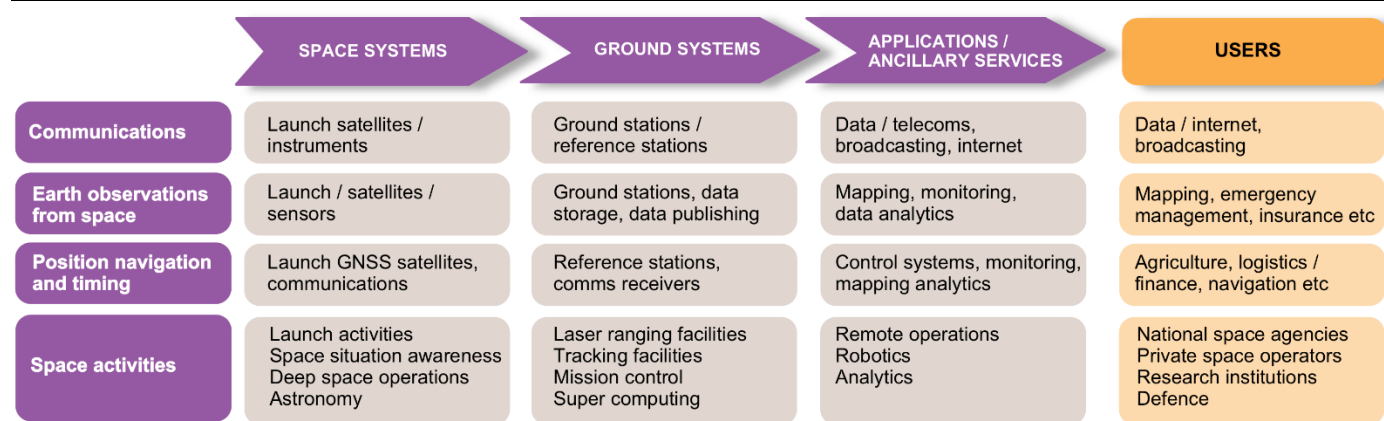
The term upstream and downstream is sometimes used in discussions on the space industry. In this case the upstream would represent manufacturing and operations and downstream would refer to space applications and auxiliary services.

Full details of the derivation of this definition is provided in Attachment B.

1.2 The space industry supply chain

An illustrative diagram of the space supply chain is shown in Figure 1.1. The supply chain is depicted as a matrix of space systems and applications and ancillary services by space services being communications, earth observation from space and position navigation and timing (PNT) (APAC, 2015).

FIGURE 1.1 SPACE INDUSTRY SUPPLY CHAIN



SOURCE: ACIL ALLEN CONSULTING

Western Australia has significant infrastructure, facilities and institutions supporting space research, space missions and space operations. A map of these arrangements is shown in **Figure 1.2** below.

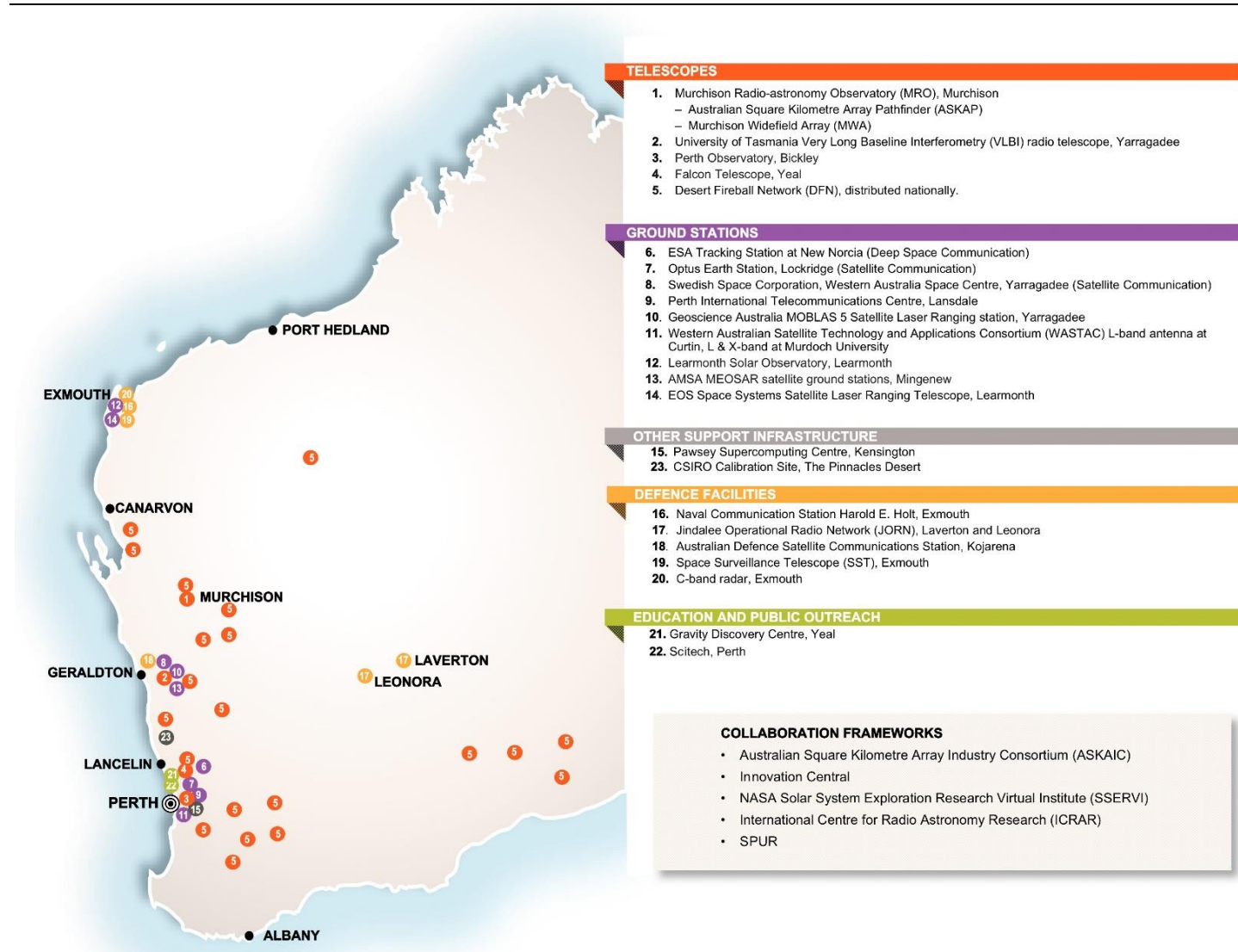
Facilities and infrastructure

These facilities include:

- telescopes
 - including the Murchison Radio-astronomy Observatory (MRO), the Very Long Baseline Interferometry (VLBI) Radio Telescope at Yarragadee, the Perth Observatory and the Falcon Telescope at Yeal, and the Desert Fireball Network (Western Australian component)
- ground stations
 - including the European Space Agency (ESA) DSA-1 at New Norcia, the Swedish Space Corporation (SSC) Western Australian Space Centre (WASC) at Yarragadee, satellite laser ranging stations at Yarragadee and Learmonth
- supercomputing
 - Pawsey Supercomputing Centre, Kensington
- defence facilities
 - Exmouth, Laverton, Leanora and Kojarena

It should be noted that these facilities have either been deliberately sited along, or taken advantage of, the Australian Academic Research Network (AARNet) fibre that connects facilities in Perth, Geraldton and Murchison. The facilities at Exmouth are taking advantage of the existing defence infrastructure.

FIGURE 1.2 SPACE INDUSTRY INFRASTRUCTURE IN WESTERN AUSTRALIA



Note: The AARNet connects Murchison, Geraldton and facilities in Perth including the Pawsey Supercomputing Centre.

SOURCE: ACIL ALLEN CONSULTING

Research institutions

The research capabilities in the four universities in Perth also represent a significant and focused capability across a wide range of disciplines in the space sector. This places Western Australia at the forefront of research in areas such as:

- Global Navigational Satellite Systems (GNSS)
- optical communications
- ground stations
- automation and remote operations
- validation and calibration

Collaborative frameworks have also been established including:

- Australian Square Kilometre Array Industry Consortium (ASKAIC)
- NASA Solar System Exploration Research Virtual Institute (SSERV)

- International Centre for Radio Astronomy Research (ICRAR).

Industry

Western Australia has around 90 companies (international, national and local) providing space derived services and applications to both the space sector and industry. Industry areas include agriculture, mining, offshore petroleum, emergency services, transport, logistics, health and human services and surveying and mapping.

There are also existing and emerging collaborative arrangements in the space applications sector including:

- Landgate SPUR
- Food Agility CRC
- Mining Research Institute
- Innovation Central
- METS/NERA collaboration
- Space Cubed
- Flux
- Innovate Australia
- Unearthed

1.3 The economic value of the space and spatial industries

There is no data available on the economic value of the space industry to Western Australia. In our national report ACIL Allen estimated that the space industry might employ around 10,000 people in Australia with a total revenue of \$3 billion to \$4 billion Australia wide.

The spatial industry captures a significant proportion of applications dependent in one way or the other on earth observations from space, GNSS positioning systems, geographic information systems, and space to ground communication systems. In 2008 we estimated that economic value to the Australian economy was between \$6 billion and \$12 billion at that time. That is the Australian economy was greater by these amounts as a result of the use and application of spatial information.

While these studies provide only a general indication of the value to Australia of space related activities the magnitude of the impacts nationwide suggest that the impacts in Western Australia are also significant given the importance of spatial and space related data and services to most of Western Australia's major industries as well as to government services such as emergency services.

The next evolution in precision agriculture is expected to be a move to digital agriculture. The Australian Farm Institute estimated that the value of agricultural production could be increased by 25 per cent through the full use of digital agriculture (Farm Policy Journal, Autumn 2018). Positioning, digital maps, sensors, control systems, autonomous vehicles and data analytics will all contribute to this.

1.4 The contents of this report

Chapters 2 to 5 discuss Manufacturing, Operations, Applications and Auxiliary Services in turn as at the time of writing this report.

Chapter 6 examines the alignment of the space industry sector with other sectors in the Western Australian economy and discusses potential areas of focus for space-based applications.

Chapter 7 reviews the factors that determine the competitive advantage of the space industry sector in Western Australia.

Chapter 8 outlines the opportunities for growth, jobs and developing a sovereign space capability in Western Australia.



2.1 Introduction

A strong resources sector and ship building industry has established manufacturing capability in Western Australia relevant to the space industry. This has been reinforced in the space sector in activities such as the installation and maintenance of satellite ground stations, radio telescopes, and laser ranging telescopes. There is also research and development capability in the development of mobile defence communication satellites.

An overview of manufacturing capability is provided in the following sections.

2.1.1 Launch vehicles

Western Australia has no identified capability in launch vehicle design. No significant research capability in related areas such as propulsion systems, propellants or materials was identified.

2.1.2 Satellites

There is increased activity nationally in the manufacture of small satellites, particularly micro and nano-satellites that utilise the CubeSat¹ standard. To date, Australia has launched four CubeSats. In Western Australia, a start-up company, PicoSat Solutions, is leveraging the technical expertise and facilities of ICRAR and a commercial picosat kit with the intention of launching a technical demonstration mission in 2019.

The Advanced Computation and Instrumentation Centre (ACIC) located in Canberra was established as a national facility to test and certify satellite systems and is available to all Australian operators. There would be little point in seeking to duplicate these facilities in Western Australia. However, there may be a case for established complementary developmental test facilities in Western Australia should Western Australian companies wish to further explore small satellite possibilities.

Western Australia has no identified capability in the design or manufacture of large satellites. Large multinationals with a presence in Western Australia identified this capability within their parent companies and a willingness to leverage this capability in Australia. They acknowledged that this would only occur in response to a commercial opportunity and would most likely utilise existing facilities on the east coast.

¹ A CubeSat is standard 10cm³ (1U) satellite that uses standard commercial off the shelf (COTS) parts. It can be combined to make larger (2U, 3U....) satellites.

2.1.3 Space-based instruments

There was identified capability within the universities in the design of space-based instruments including personnel from other countries with space instrument manufacturing and testing experience. This expertise is currently being applied to ground-based instruments, but with access to facilities such as the Advanced Sensing Technologies Laboratory at the University of Western Australia (UWA), and the Electron Science Research Institute at Edith Cowan University and the space environmental test facilities at the ANU, this expertise could be leveraged to design and build a satellite instrument, an instrument for a planetary mission or an instrument for the International Space Station.

Some of the capability established to support defence projects, the Murchison Widefield Array (MWA) and the DFN could be leveraged to develop space-based instruments and small satellites.

2.1.4 Ground stations

The most significant manufacturing activity in Western Australia relates to the installation and maintenance of ground infrastructure. This includes ground stations for deep space communication, Earth Observation, radio astronomy and space debris tracking. A list of ground stations in Western Australia is provided at Attachment C.

There is no current capability in Western Australia for manufacture of satellite ground stations and optical satellite laser ranging telescopes. The equipment is designed and manufactured overseas, or elsewhere in Australia, then assembled, commissioned and maintained in Western Australia. This is still an important activity for building technical capability in Western Australia. It also provides ongoing business for Western Australian companies.

There are likely to be opportunities for the installation of further ground stations in the future. The European Space Agency (ESA) New Norcia Station, designation DSA-1, has a 35 m deep-space antenna with transmission and reception in both S- and X-band. In 2015, a new 4.5 m radio dish was installed. This offers a wider field of view than the 35 m antenna and can acquire signals from newly launched spacecraft even when the position is not precisely known. ESA has expressed interest in expanding these facilities at New Norcia.

The distance between the east and west coast of Australia makes it attractive for operators to establish facilities on both coasts. Optus satellites, Telstra and NBNCo have all established satellite communication ground stations on the east and west coasts and operate their satellites from the east coast. Many of these are located at the Perth International Telecommunications Centre.

The Swedish Space Corporation (SSC) Space Australia is a wholly owned subsidiary of SSC. SSC Space Australia established the Western Australia Space Centre (WASC) at Yarragadee in 2012. This \$8 million facility includes seven ground stations. SSC Space Australia chose the site at Yarragadee for its ability to support early data recovery from satellite launches from most launch sites around the world and access to the existing infrastructure established by Geoscience Australia. SSC Space Australia uses local contractors for installation and maintenance. ACIL Allen understands that there are no plans to expand these facilities at the present time.

2.1.5 Mobile satellite communication terminals

The largest commercial manufacturing activity in Western Australia has been the development of electronic systems to support mobile defence satellite communications. In 2015, L3 Oceania was awarded a \$37.8 million contract to supply SATCOM terminals to the Australian Defence Force (ADF), allowing them to deploy an integrated wideband satellite communications capability. L3 Oceania maintains these systems and develops new electronic and software solutions to enhance its performance. In 2017, L3 Oceania reported \$50 million in revenue plus another \$5 million in exports. They employ 70 people of which 50 are engineers and have a strong internal research capability. L3 Oceania has its origins in North Fremantle where a group of young engineers established the company in 1984 with the aim to master undersea acoustic control systems for the offshore oil and gas industry. L3 Oceania is still headquartered in Fremantle with offices in Wollongong and Cairns. L3 Oceania continues to develop marine sensor networks. This is discussed below in Section 2.3.6.

2.1.6 Laser ranging and space debris tracking telescopes

There is an increasing number of telescopes being established in Western Australia for monitoring the space environment. Western Australia's location in the region, and dry stable weather, make it an attractive site for monitoring the space environment with optical telescopes. The low level of radio interference also makes it an ideal location for monitoring the space environment with radar.

The defence C-band radar and US Space Surveillance Telescope (SST) are both being installed at Exmouth. L3 Oceania is managing the logistics, installation and maintenance of the SST. The commercial EOS Space Systems SLR Telescope is being installed at Learmonth to take advantage of the existing defence infrastructure. All this equipment was manufactured overseas or on the east coast but will be installed and maintained by local contractors.

EOS Space Systems indicated that there was interest in establishing additional Laser Ranging Telescopes in Queensland and Alice Springs to add geographic and weather diversity to the network. There is a possibility of a future SLR ground station in Laverton Western Australia.

The DFN was developed by Prof Phil Bland to observe meteorites after he joined Curtin University from the space instrumentation group at Imperial College London. The Curtin Department of Physics and Astronomy has established a team of 20-25 technicians, engineers and astronomers to integrate and test the autonomous optical observatories for the DFN. The DFN is now a network of 52 observatories in Australia and 40 observatories overseas with a further 150 to be deployed overseas in the next 12 months. The telescopes are designed to operate remotely in harsh conditions for 2 years and transmit data to a central server. In 2017 Curtin University announced a partnership with Lockheed Martin to investigate how the DFN could support space situational awareness (SSA).

The potential to use the Murchison Wide Field Array (MWA) for Space Situational Awareness (SSA) has also been identified. Passive radar with the MWA can detect and track space debris in Earth orbit over a very wide field of the near space environment. When the MWA detects a target, more sensitive instruments such as optical laser ranging telescopes can then be tasked for detailed observations.

The Advanced Signal Processing Group at Curtin has design capabilities in multiple object tracking solutions and information fusion that are essential in supporting SSA. The Satellite Research Group (RSSRG) conducts research in the field of quantitative Earth observations from space. Quantitative satellite remote sensing aims to record geophysical quantities that inform on the environment, coastal and offshore waters around Australia.

2.1.7 Radio astronomy telescopes

The construction of the Australian Square Kilometre Array Pathfinder (ASKAP) and the MWA at the Murchison Radio Observatory (MRO) have developed capability within CSIRO and ICRAR for design and manufacture of advanced electronic system for remote operation in hostile environments. ICRAR have established electronics laboratories, clean laboratories and test laboratories staffed by experienced engineers and technicians to support the development of the MWA.

ICRAR has established relationships with local companies to solve a range of manufacturing, power, data management flows involved in establishing the SKA project. Some of the companies that have provided services to ICRAR include IBM, CISCO, DDN Storage, NVIDIA, Balance Utilities Solutions, Amazon, SGI Systematics, Thoughtworks, Western Digital (HGST), Kakadu Software, ThinkBottomUp and Intel. Of these companies, eight have a presence in, or are based in, Western Australia.

In 2012 Poseidon Scientific Instruments (PSI) was awarded a \$1.3 million MWA contract to develop and deliver 64 production ready receivers. PSI was internationally recognised for breakthrough technology in oscillators emitting low-noise microwave signals which allowed radars to see further and with higher resolutions.

Following the MWA contract, Poseidon was acquired by Raytheon. In 2017 MWA underwent an upgrade. Over a period of 16 months, 128 new antenna stations were assembled on the MWA taking the total number of antennas to 256. The work was completed by a team of MWA staff, students from Curtin University and international project partners, as well as contractors from GCo Electrical, a local Geraldton company.

Balance Utilities Solutions focussed on feasibility studies and development of prototypes for radio-quiet power solutions for phase one of the Low Frequency Aperture Array (LFAA). There are likely to be ongoing opportunities arising in radio physics, software and data management that potentially provide opportunities in niche markets for companies in Western Australia.

CISCO provided support for the design and development of network systems for the Central Signal Processor (CSP) pre-construction design package for the project.

2.1.8 GNSS reference stations and GNSS receivers

Western Australia does not manufacture GNSS reference stations nor GNSS receivers. However, there are companies that install and operate commercial CORS (Continuously Operating Reference Station) networks. Trimble have a network of reference stations in Western Australia and have developed the GPSBase, GPSNet, and Trimble Reference Station software.

The GNSS Research Centre at Curtin University is developing new models and methods to realise the full potential of future GNSS systems to help industry benefit from the high accuracy and high-integrity of tomorrow's geospatial systems. Fugro, an international geophysics and positioning company with offices in Perth, collaborates with Curtin on some aspects of the GNSS research.

2.1.9 Other ground-based application

Woodside is developing capability in autonomous systems to support their oil and gas business by improving safety and efficiency. This includes the manufacture of sensors and prototyping systems before going to the market for operational systems. They source from a global market but actively invest in Australia and Western Australia because of a long-term vision to build a strong local capability.

Woodside have a 5-year partnership with NASA to explore automation, remote operation and the robot/human interface. As part of this partnership, Woodside hosts one of eight NASA robots and NASA engineers within their innovation team. Of the other seven robots, one is on the International Space Station, one is at General Motors, and five are at the Johnson Space Centre. This collaboration promotes the exchange of knowledge and expertise. NASA is benefitting from Woodside's experience in remote operation in harsh environments and Woodside is benefitting from NASA's experience in automation and the human robot interface. In parallel with this program, Woodside is stimulating innovation in data analytics and machine learning through Innovation Central (a partnership between CISCO, Curtin University and Data 61).

The Microelectronics Research Group at UWA is undertaking world leading research in the innovative combination of micro-electromechanical systems with infrared sensor technologies for fourth generation infra-red systems. The advanced Sensing Technologies Research Group is exploring the next generation of sensing technologies needed to solve remote operational challenges. UWA's collaborative activities include the Defence R&D hub, the NSAS SERVI Centre and the Woodside robotics project.

The Frequency and Quantum Metrology research group at the UWA is involved in ESA's Atomic Clock Ensemble in Space (ACES) mission. The team have built an ultra-stable and accurate atomic optical lattice clock. Improvements in timing and synchronisation of clocks around the globe will improve the GPS satellite system, radar systems, optical fibre communications and many other autonomous systems.

UWA is also using Cryogenic Sapphire Oscillators for low noise transducers for gravity wave detection, and to support a collaboration with Japan. Two high precision oscillators have been delivered to the National Metrology Institute of Japan (NMIJ) and one to the National Institute for Information and Communication Technology (NICT), Japan. Using the oscillators and a ground terminal at UWA, NICT demonstrated a satellite to ground laser link. The oscillator will support laser calibration for multiple dishes and nanosecond timing frequency locking to keep the signal coherent. Optical communication is a potential area for development that would be suitable for trialling in Western Australia given its location and geography.

In addition to supporting SATCOM systems, L3 Oceania has also developed intelligent undersea network solutions. These systems include sensors for spatial awareness solutions and maritime domain awareness systems, such as the AUSSNet. AUSSNet can gather, process, store and discreetly transfer undersea surveillance data via satellite and/or hydro-acoustic telemetry links to land, air, space or sea assets to enhance situational awareness. This self-contained sensor network is recoverable, reconfigurable and reusable.

The Edith Cowan University (ECU) houses the Robotic and Autonomous Systems Research Group that is currently investigating the application of deep learning approaches to sending and control methods. The Applied Artificial Intelligence Laboratory is exploring visual teach and repeat learning for robotics. ECU's Security Research Institute also houses the only purpose-built facility for cyber security research at an Australian University.

Murdoch University is developing a research program aimed at developing Mars capable drones. Autonomous vehicles, robotics and operations in remote environments is a high priority for Western Australia's mining and offshore oil and gas industries. There are potential synergies between the application of these technologies in a space environment and in the remote operations of the mining and petroleum sector in Western Australia.

2.2 Summary

The most significant manufacturing activity in Western Australia relates to the installation and maintenance of ground infrastructure. This includes ground stations for deep space communication, Earth Observation, radio astronomy, satellite laser ranging, situational awareness and radio-quiet power systems.

Other areas of research, design or manufacturing in Western Australia are associated with development of electronic systems for mobile defence satellite communications, development and testing of ground-based instruments, design and manufacture of advanced electronic systems for remote operation of radio astronomy telescopes and receivers, network systems, remote sensing and remote operations for robotics and autonomous vehicles operating in hostile environments. There may be potential for development of capabilities in space-based sensors, control systems and robotics.

There is no capability in launch facilities or design and manufacture of large satellites. There is some research and development in design and manufacture of small satellite systems, but it appears to be at a very early stage of development.

A summary of manufacturing capability is provided in **Table 2.1**

TABLE 2.1 MANUFACTURING

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Large satellite design, manufacture and test	Western Australia does not manufacture or test large satellites	N/A	N/A
Small satellite design, manufacture and test	Emerging design and integration capability in universities and start-ups. Picosat Solutions is developing a small satellite demonstration mission. Primes have access to capability in parent company.	No space environmental test facilities in Western Australia. Access to Advanced Instrumentation and Technology Centre (AITC) L3 Oceania has cleanroom facilities in Brisbane that can be called upon	Potential

Instrumentation and component design and manufacture	Some examples of mature component capability within SMEs. L3 Oceania VSAT electronics, AUSSNet and Trimble.		Internationally competitive with access to global supply chain.
	Emerging capability in universities, start-ups and SMEs. Advanced Sensing Technologies Some examples of mature capability being translated to space applications, MWA, Desert Fireball Network. UWA atomic optical lattice clock, Murdoch University autonomous vehicles and drones, Woodside robotics and sensor development.	Laboratory at UWA, Electron Science Research Institute (ESRI) at Edith Cowan University, MWA, DFN, NASA SERVI Centre.	Emerging competitiveness.
Laser ranging and space debris tracking telescopes	Mature capability in the installation, operation and maintenance of satellite laser ranging telescopes.	EOS Space Systems SLR, NASA SLR, Defence SST, Desert Fireball Network, MWA	Internationally competitive. Southern hemisphere location highly sought after.
Launch vehicle design, manufacture and test	No capability.	N/A	N/A
Ground station design and installation.	Mature installation and maintenance capability. Some VSAT design capability identified in industry.	Access to land with clear skies, low noise, and spectrum access. Good communications infrastructure at existing sites.	Internationally competitive. Southern hemisphere location highly sought after.
GNSS reference station manufacture	Mature industry, installation and maintenance.	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)



3.1 Introduction

The Western Australian space industry has mature capabilities in operations, particularly in remote and often harsh environments. Western Australia hosts a significant percentage of Australia's ground infrastructure.

Figure 1.2 shows that ground stations and supporting facilities are clustered around existing infrastructure for data transmission, power and water. Beyond Perth, the main communications infrastructure is provided by AARNet and Defence².

While this infrastructure involves local support, a significant proportion of it is controlled remotely from outside the state. Operations in each area are discussed in the following sections.

3.2 Deep space communication

The ESA New Norcia station, DSA-1, is remotely controlled from the European Space Operations Centre (ESOC) but operated and maintained by Inmarsat Solutions. ESA issued a tender for maintenance and operational support in late 2017 with a published value of "more than €500,000". As discussed in Section 2.1.4 above, ESA is investigating further investment at New Norcia.

3.3 Satellite communication

Optus has ten ground stations in Western Australia, eight supporting national services and two supporting international services. These ground stations are accessed remotely from the Optus Satellite Operations Centre in Belrose, Sydney, and are used to operate the Optus and NBNCo communications satellites.

The seven SSC Space Australia ground stations at the WASC provide commercial services to civil and defence customers from North America, Europe and Asia with an estimated annual revenue of approximately \$10 million. A permanent staff of four people support the site 24/7 with an increase in staff during construction.

The Australian Maritime Safety Authority (AMSA) operates six satellite ground stations at Mingenew, as part of the international Medium Altitude Earth Orbit Search and Rescue (MEOSAR) system. The facility detects and locates beacon activations from Emergency Position Indicating Radio Beacons (EPIRBs), Personal Locator Beacons (PLBs) and Emergency Locator Transmitters (ELTs) from

² AARNet is Australia's Academic and Research Network. It is operated by AARNet Pty Ltd, a not for profit company owned by CSIRO and the Universities.

overhead satellites and forwards the information to the Mission Control Centre in Canberra, initiating search and rescue response.

3.4 Earth observation

The Moblas 5 satellite laser ranging (SLR) facility at Yarragadee is part of a network of NASA Moblas facilities around the world and plays an important part in the Australian and International geodetic framework. The facility in Western Australia has been operational since 1979 and is managed and operated by Geoscience Australia.

The observatory also includes the University of Tasmania (UTAS) Very Long Baseline Interferometry (VLBI) radio telescope which was established as part of the AuScope Program. The site also hosts GNSS receivers along with a DORIS³ transmitter and time reference equipment.

The Western Australian Satellite Technology and Applications Consortium (WASTAC) is a consortium of state and federal departments and universities whose main objectives are to maintain a reliable, comprehensive and accessible archive of NOAA-AVHRR MODIS and SeaWiFS satellite data. WASTAC includes an L-band antenna at Curtin, and L & X-band antennas at Murdoch University.

In 2017 the WASTAC members worked as part of the Australian National Ground Segment Technical Team (ANGSTT) to establish a coordinated national network of ground stations. The ANGSTT facilitates collaboration between the Australian public-sector satellite operators providing a framework for increased collaboration with international operators and the commercial sector to grow the Australian space economy.

Australia's diverse ecosystem makes it a perfect location for calibration, validation and certification of satellite instruments. 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 an existing network of calibration sites in Australia and they are in the process of establishing a new site in The Pinnacles Desert in Western Australia.

3.5 Space situational awareness

EOS Space Systems are currently commissioning the Satellite Laser Ranging (SLR) station at Learmonth in Western Australia. Local contractors will be used for the ongoing maintenance, but the telescope will be remotely operated from the EOS facility at Mt Stromlo in Canberra or 1RSU in South Australia⁴. EOS estimate that space debris tracking services will be worth approximately \$4 million per year for combined defence and government services. EOS are interested in the possibility of using the MWA as a wide field survey if assured and persistent observations are possible. EOS are also interested in the observations being taken by the Bureau of Meteorology at Learmonth and the research being conducted at Curtin University related to atmospheric drag and radio occultation. EOS has a need for data centres to be located near the operations centres. The Pawsey Supercomputing Centre has been considered but no evaluation has been conducted.

The Learmonth Solar Observatory is jointly operated by the Bureau of Meteorology Space Weather Services and the US Air Force. The observatory is the site of one of six solar velocity imagers worldwide. The GONG (Global Oscillation Network Group) provides data for helioseismological studies of the interior of the Sun. The observatory operates an optical telescope to monitor sunspots and solar activity, a radio telescope with three parabolic dish antennae to monitor solar radio flux on eight discrete frequencies in the range 245-15,400 MHz, and a solar radio spectrograph which sweeps through a frequency range of 25-180 MHz every three seconds to monitor solar radio bursts.

³ DORIS stands for Doppler Orbitography and Radiopositioning Integrated by Satellite

⁴ 1RSU stands for Radar Surveillance Unit operated by the Royal Australian Airforce

3.6 Astronomy

The Australia Telescope National Facility (ATNF) includes the Australian Square Kilometre Array Pathfinder, Murchison Radio-astronomy Observatory (MRO), Canberra Deep Space Communication Complex (CDSCC), Parkes Radio Telescope, Australia Telescope Compact Array, Mopra Radio Telescope and Australia Long Baseline Array.

These facilities are all managed, maintained and operated by CSIRO. CSIRO 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.

This is a capability that could be leveraged to increase the local operation of facilities in Western Australia.

The volume of data generated by observatories worldwide doubles every six to 12 months. The challenges of managing and processing this data is being addressed through research and development programs of the ICRAR supported by UWA and Curtin. The Data Intensive Astronomy team at UWA comprises researchers from astronomy and industry addressing the challenges of managing the flow of data from the SKA.

Curtin University also leads a range of efforts in engineering, computational science and data analytics built around the Pawsey Supercomputing facility. This has led to the establishment of the Curtin Institute for Computation (CIC) and Innovation Central. Curtin University has a strong track record working with industries, particularly in robotics, control systems, signal processing, positioning and computer vision.

All these activities provide opportunities for collaboration with companies with a base in Western Australia. While there are extremely important examples of collaboration to date, it would appear from consultations and research undertaken by ACIL Allen that these are yet to be fully exploited by Western Australian companies with service offerings relevant to the space sector.

3.7 Aligned industries

There are many similarities between remote operation of space assets and remote operation in the mining and energy sectors. Mining and oceanographic devices often require remote and robotic operations of sophisticated heavy equipment in hostile environments (extreme pressure, high-temperatures, low-light etc), while at the same time acquiring complex data and relaying them back to base. In many cases these devices operate either with a degree of autonomy, or are remotely driven using sophisticated visualisation capabilities, similar to those that will be required for planetary robotic missions.

3.8 Summary

Western Australia has mature industry capabilities in maintenance and operation of space related activities often in remote and harsh environments. This includes operations in astronomy, deep space communications, satellite communications, earth observations from space, space situational awareness telemetry, tracking and control and defence communications.

This activity concerns mainly operation of ground station facilities clustered around communications infrastructure provided by AARNet and Defence. These operations employ highly trained professionals and technicians providing a small base of technical capability for space support services. There is also significant computational capability at the Pawsey Supercomputing Centre located in Perth. Neither the Pawsey centre nor AARNet are available to commercial users.

Western Australia's geographic location in the southern hemisphere is particularly suited to communications for civil and defence purposes with North America, Europe and Asia. There is an opportunity to attract more ground station operators to Western Australia through the availability of good infrastructure and a skilled workforce. There is also a risk that improved infrastructure will support remote operation from the east coast or an international site. This can be mitigated through

the development of an ecosystem around the collation and timely use of data, and the provision of a highly skilled local workforce.

SSC Space Australia reported no plans to expand its operations at the Western Australian Space Centre at this time. The European Space Agency has expressed interest in expanding its deep space tracking families at New Norcia. NASA is in collaboration with Woodside in the trialling and testing of robotics and would be aware of Western Australia's capabilities.

A summary of space operations in Western Australia is provided in **Table 3.1**.

TABLE 3.1 OPERATIONS

Capability	Level of maturity	Relevant infrastructure	International competitiveness
Satellite communications	Mature commercial capability	Optus Lockridge Earth Station, SSC Western Australian Space Centre, Perth International Telecommunications Centre	Competitive
	Emerging optical communication capability	Collaboration between UWA and NICT	Emerging capability
Earth Observation and meteorology Telemetry, Tracking and Control (TT&C)	Mature commercial capability for large satellites	SSC Western Australian Space Centre	Competitive commercial operations
	Mature established government operations	WASC is part of national ANGSTT ground station network, BoM Learmonth Solar Observatory	Southern hemisphere location highly sought after
	Mature operation sin calibration, validation and certification of space instruments	WASTAC L-band antenna at Curtin, X and L-band antennas at Murdoch, UTas VLBI ground station at Yarragadee.	Research stage with some commercial activity
	Mature research programs		
Deep space TT&C	Mature capability. Inmarsat current operators	ESA New Norcia	Internationally competitive
Telescope operation for astronomy	Mature capability	Murchison Radio-astronomy Observatory (includes Australian Square Kilometre Array Pathfinder and Murchison Widefield Array), Pawsey Centre, Desert Fireball Network, Zadko Observatory, Falcon Telescope, Perth Observatory, UTas VLBI ground station	Internationally competitive Potential to increase the local operation of facilities in WA
Space surveillance, including satellite laser ranging, space debris tracking and space weather	Some commercial operations conducted from Western Australia but operated from east coast	EOS Space Systems SLR, Zadko Observatory, Airbus Saffron Launchers, Numerica, Desert Fireball Network	Competitive niche but potentially growing markets internationally
	Mature government capability for space weather	BoM Learmonth Solar Observatory, Space Surveillance Telescope, C-band radar, Falcon Telescope	
	Emerging research capability	Curtin Advanced Signal Processing	
Launch services	N/A	N/A	N/A
Satellite calibration, validation and certification	Mature government capability	CSIRO and Geoscience Australia calibration sites, CSIRO automated calibration robot, new site in The Pinnacles Desert	Internationally competitive location and infrastructure
Defence operational capability	Defence has a mature operational capability in Western Australia	Naval Communication Station Harold E. Holt, Jindalee Operational Radio Network (JORN), Australian Defence Satellite Communications Station, Space Surveillance Telescope (SST), C-band radar	N/A

NOTE: TT&C MEANS TELEMETRY, TRACKING AND CONTROL

SOURCE: ACIL ALLEN CONSULTATIONS



3.9 Introduction

There are many applications of space observations and data in the upstream and downstream sectors of the space supply chain in Western Australia. The upstream sector has been discussed in Chapters 2 and 3. The downstream sector includes many applications in the private or public sectors utilising communications, PNT, Earth Observation from Space and data analytics. Most of these are commercial applications, developed to meet industry or government needs in sectors such as defence, agriculture, mining, marine and offshore oil and gas operations, emergency services, construction, transport, logistics, surveying and mapping.

The Western Australian economy is characterised by three important sectors: agriculture; mining; and offshore oil and gas operations. These sectors are significant users of data derived from space and are a market for space-based applications. There are also opportunities in areas such as emergency services, construction, logistics, navigation, surveying and mapping that also use these services.

Discussion of applications is outlined in the following sections.

3.10 Defence

Defence and security are significant users of space applications for communications and intelligence. The Defence White Paper notes that space-based and space enabled capabilities will continue to expand over the next 20 years (Department of Defence, 2016). The ADF is reliant on space-based satellite systems to support its networked capabilities and to communicate and fight when deployed on operations. The White Paper stresses the importance of protecting these systems from attack or attempts to degrade them. As discussed in Chapter 3, the Government has indicated its intention to strengthen defence space surveillance and situation awareness capabilities including the relocation of a United States optical space surveillance telescope to Australia.

The White Paper also states that there will be more emphasis placed on the joint forces bringing together different land, air and space intelligence and capabilities. To this end one of the six capability streams includes:

“The Intelligence, Surveillance, Reconnaissance, Space, Electronic Warfare and Cyber capabilities that ensure our forces have superior situational awareness” (Department of Defence, 2016).

Additional investment is planned in ADF space capability, including space-based and ground-based intelligence, reconnaissance and surveillance systems. This program also has implications for defence related contractors with operations in Western Australia. The DFN discussed previously is an important example of such investments.

3.11 Agriculture

Agriculture is a significant component of the Western Australian economy. The total value of agricultural production in Western Australia was \$13 billion in 2017. The value of exports of agriculture from Western Australia amounts to some \$7 billion.

The agricultural industry in Western Australia competes in global markets and must maintain productivity to survive. The grains industry was one of the earliest adopters of precision farming techniques in Australia and the world for that matter. Controlled traffic farming (self-steering tractors and harvesters with GNSS guidance) was developed early in Western Australia with rapid adoption. It was supported by several innovative companies in Western Australia.

Today larger companies are major suppliers of precision agricultural services to the sector. There are also several grower groups and agricultural consultants that provide services to farmers in the use and application of space-based data and systems. The main applications in agriculture are in harvesting, variable rate fertiliser application, crop monitoring and the use of autonomous machinery. The issue going forward is development of the communications infrastructure to enable farmers to take full advantage of data both of position and imagery data.

Improvements in weather forecasting are also important to Western Australian farmers, particularly those in the grains sector where timing of planting and harvesting is critical. Space based data has significantly improved the ability of the Bureau of Meteorology to forecast weather events important to farmers.

AgroMeteorology Australia is an Australian company based in South Perth that provides operational climate forecasts and crop monitoring at the large scale. This work is underpinned by agro-climatic modelling that combines trends in climate variables, agronomic data, climate variability and technological advances. Other companies providing services to the agricultural sector include NGIS, Trimble, Gaia Resources, Astron, Ovaas, iPaddock and the Facey Group.

NGIS developed software for vegetation analysis that was purchased by Wesfarmers and is now marketed as Decipher. This software draws on satellite-based imagery to analyse and define vegetation cover across Australia and the world. Decipher enables farmers to compare crop performance to improve decision making to get the most out of every hectare under production.

Trimble operates an onshore space based GNSS correction service to supply agriculture and construction. While the principal office is in Brisbane, the company has an office in Perth where its agricultural consultancy business is based. Trimble has developed a new space-based correction technology RTX that can provide correction to GNSS to 2 cm accuracy. Trimble operates through resellers including Case IH, New Holland, and Vantage NEA.

Trimble agriculture services in Perth develops products and services for the agricultural sector based on their GNSS correction technology and related control and monitoring systems. The process started in the early 1990s with small Western Australia and Queensland companies developing GPS steering. Trimble now provides end to end solutions for agriculture including control hardware, applications and data services. Applications include irrigation control systems, sprays, spreaders, feed and water and data monitoring services. Other companies that operate in this area are Top Con, Leica and John Deere.

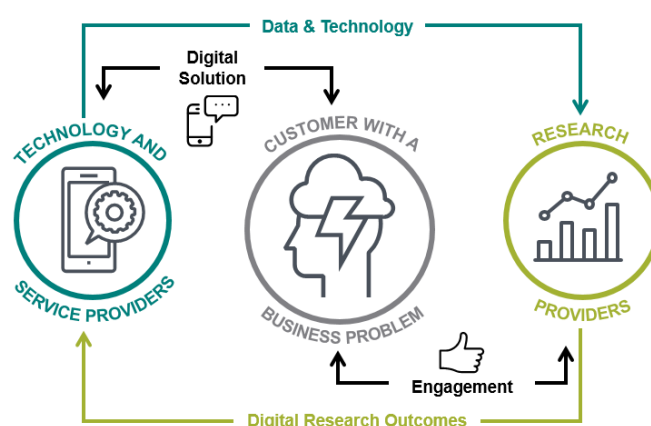
Important trends in this area have been the development of autonomous tractors and the availability of ubiquitous data from satellites. Given the magnitude of the data transfers involved, it is not feasible to deliver data with modems and sim cards in areas where phone signals are deficient. Getting data over satellite is far more efficient and gets it to where it is useful. The power in autonomous vehicles is in the computing and data applications that they draw on. Connectivity is therefore important to realising the benefits of precision agriculture.

There are several organisations that provide facilities for research collaboration. The Cooperative Research Centre for Spatial Information (CRCSI) has been an important institution for the implementation of collaborative research. Through its collaboration mechanism 43 PL joint activities between research and industry were assisted. The funding under the CRC program for the CRCSI concludes at the end of the 2017-18 financial year.

The CSIRO Floreat site hosts the Centre for Environment and Life Sciences (CELS). CELS is recognised for its expertise in the development of rigorous algorithms for the classification of vegetation types. These algorithms have been applied to the National Carbon Accounting System, and to urban and infrastructure mapping.

The Food Agility CRC was established in 2017 to empower Australia's food industry to grow its comparative advantage through digital transformation. Its main office is in Sydney but has a presence in Perth and is involved in innovation in Western Australian agriculture. The CRC model for collaboration is summarised in **Figure 0.1** below. The figure illustrates the importance of the relationship between the research providers, the research institutions and the customer with the business problem.

FIGURE 0.1 INNOVATION PROCESS FROM FOOD AGILITY CRC



SOURCE: [HTTP://WWW.FOODAGILITY.COM/OVERVIEW/](http://www.foodagility.com/overview/) ACCESSED ON 10 MARCH 2018

Another important organisation in fostering collaboration has been Landgate. Landgate was established under the *Land Information Authority Act 2006* (LIA Act) to be an innovative, commercially-focused statutory authority responsible for Western Australia's land and property information. Landgate supports the Shared Location Information Platform (SLIP) that has provided access to location data published by Landgate. Landgate has a panel contract of state and local government agencies for provision of imagery.

The organisation is now in transition to one that provides spatial data and property information with the intention that the products and services it traditionally developed will now be developed by private sector organisations. To this end Landgate has created SPUR as a vehicle for collaboration with the private sector to foster innovation in the use of its spatial data.

SPUR is a location technology hub bringing together a selection of Landgate's services to provide developers and companies with access to data, resources and key contacts to facilitate innovation in the development of products and services utilising Landgate's location data. The aim is to support a pipeline of partnership, investment opportunities and support for emerging Western Australian based location technology businesses. Three elements underpin SPUR activities: collaboration; stimulation and acceleration.

Box 0.1 illustrates some of the products and services that have been developed based on Landgate data. Pastures from Space and Firewatch were developed by Landgate prior to the reform to the organisation. Instatruck and Infarm were developed with the assistance of SPUR.

BOX 0.1 PRODUCTS AND SERVICES ARISING OUT OF LANDGATE AND SPUR***Pastures from space***

The Pastures from Space program provides estimates of pasture production during the growing season by means of remote sensing. Satellite data is used to accurately and quantitatively estimate Pasture Biomass or Feed On Offer (FOO) or combined with climate and soil data is used to produce Pasture Growth Rate (PGR) estimates. It was developed by a consortium of Landgate, CSIRO and the Western Australian Department of Agriculture.

Infarm developed by Western Aerial Mapping

Infarm is a drone to tractor data processing solution that allows farmers to spot spray fallow weeds using their existing farm machinery. Drone images, collected from the paddock, are uploaded into the Infarm processing platform where our unique weed identifying algorithm is used. The result is a tractor ready file that can be uploaded into farmers standard tractors. Our data then controls the nozzles turning them on and off depending on the presence of weeds.

SOURCE: LANDGATE

Finally, the Rural Research and Development Corporations (RDCs) have recognised the importance of precision agriculture to the future of Australian agriculture. A Digital Agriculture Task Force for Australia has been now established to facilitate the development of digital technology in Australian Agriculture. This is an area where Western Australian farmers and research institutions are well placed to contribute.

3.12 Mining and oil and gas

The mining industry in Western Australia employs spatial and space related technologies for several purposes. Western Australian mining companies have been one of the earliest adopters of autonomous mining vehicles and have been active in developing robotic mining. The mining sector draws on space-based data and services for several of its functions. Satellite imagery is employed in vegetation and remediation mapping requirements of operating licences. GNSS is utilised in mining operations including guidance for autonomous vehicles and operations.

In the offshore sector GNSS services are used for drill rig positioning and navigation. Hyperspectral satellite imagery is used for shallow water bathymetry. Data derived from satellites is also used to monitor weather and the marine environment to assist in managing extreme weather events.

The CSIRO Oceans and Atmosphere team in Perth is located at the Indian Ocean Marine Research Centre (IOMRC) at UWA. The IOMRC is a collaboration between CSIRO, the Australian Institute of Marine Science, UWA and the Western Australian Department of Fisheries. This group has expertise in using satellite imagery for monitoring currents, coastal water quality and oil and gas spill detection. They have established commercial relationships in Western Australia.

The large mining companies in Western Australia are understood to have invested significantly in digital mining techniques including autonomous vehicles. Companies such as Rio Tinto, BHP, Fortescue Metals and Woodside explored advanced mining and operations techniques including in some cases autonomous mining vehicles. Western Australia is the largest market for autonomous mining vehicles in the world. ACIL Allen was advised that of around 60 large autonomous mining trucks in operation around the world, 40 are in Western Australia.

Autonomous vehicles rely on positioning data, sensors and GIS systems to operate. The CRCSI reported that there are two Space-based Augmentation System (SBAS) demonstration projects being conducted in Western Australia. Such systems draw on spatial data, digital models of mining areas, storage and sensors.

Woodside Petroleum for example has significant in-house research capability with expertise in remote operations. The company is developing its own sensors and control systems with an in-house

capability for rapid prototyping. The company recognises that artificial intelligence is a potential enabler to remote operations and robots. The capability can be transferred between robots.

Consultations with the industry suggest that rates of adoption in smaller mining companies is lower than in the large mining operations. ACIL Allen was advised that adoption of new techniques in mining is slower than in agriculture because of the regulatory requirements that need to be addressed and the rigorous compliance with safety standards.

The Minerals Research Institute of Western Australia (MRIWA) is a statutory body established by the government to support investment in and operation of globally competitive minerals industry in Western Australia. MRIWA's primary function is to provide and administer funding grants to support minerals research. It also collaborates with research and government entities in Australia and overseas.

Fugro provides GNSS corrections to offshore services and to Trimble for onshore corrections. Their signal is used for vessel monitoring in conjunction with Automatic Ship Identification (AIS) and weather forecasting in the region. As discussed in Chapter 3 Fugro uses the Inmarsat L band signal that will be retired soon. Fugro may look to drawing on Low Earth Orbit satellites for its space-based signals in future. Fugro has been part of 43PL of the CRCSI and collaborates in research with Curtin University. This collaboration is based on in kind inputs into this research such as access to signal and related activities.

An innovation precinct addressing the mining industry is being established in Perth through a collaboration between the Mining Energy and Technical Services (METS) organisation and National Energy and Resources Australia (NERA). The collaboration will seek opportunities in:

- data science, automation and robotics
- capability that will deliver skills that can be used in the mining industry
- secure remote operations in Western Australia

This will focus on establishing the skills to manage the sensors and the data they collect. Innovation in commercial operations is focussed on return on investment rather than longer term research. This collaboration will focus on the precompetitive stage of innovation but with a central goal of developing capabilities that can deliver a return on investment in the short to medium term.

The CSIRO Australian Resource Research Centre (ARRC) is part of the National Resource Science Precinct in Perth. The ARRC was opened in 2001, when nearly 200 research and support staff from CSIRO and Curtin University came together with the vision of creating a petroleum and minerals centre of expertise for the South-East Asian region. The ARRC has expertise in the use of hyperspectral imaging for mineral mapping. Using the Japanese ASTER instrument on the NASA TERRA satellite, CSIRO have developed the ASTER Geoscience Map of Australia. This map is the world's first continent scale map of the Earth's surface mineralogy.

3.13 Other applications

Space based data including communications, earth observation from space and PNT are also applied in many areas of government and business activities in Western Australia.

Earth Observation from Space has applications in many areas of the Western Australian economy including vegetation mapping, emergency services, mapping and land data.

Firewatch is a spatial map-based product that was developed by Landgate. It provides information to the public and industry on the location of fire threats across Australia. With the reforms to Landgate Firewatch will be passed to fire and emergency services and research and development will be done by UWA.

Instatruck, developed in conjunction with Landgate (SPUR), is an online truck-matching platform with the potential to reconfigure the current land transport industry in Western Australia. By leveraging new technology, Instatruck improves system efficiency by allowing customers to source the closest, most suitable truck for their needs whilst maintaining high standards of safety.

A Perth based company NGIS provides spatial services to a wide cross-section of industry in Western Australia and Australia. Their services draw on satellite imagery and positioning services. Examples of its clients includes delivery services, agriculture and government land and property agencies.

Positioning services are also finding applications in transport and logistics and in future may have an important role to play in intelligent transport systems as well as in autonomous vehicles.

3.14 Summary

There are applications and services in several areas of the space supply chain that are actively being pursued by research institutions and industry in Western Australia.

These include the use and application of data derived from space which includes communications, earth observations from space and PNT. This area is growing in Western Australia as it is in Australia and globally. It is the area where many future jobs will be created.

The commercial businesses that provide these services are national and global. However, those companies that provide services to the agricultural, mining and offshore petroleum industries are likely to develop capabilities that will provide a point of differentiation compared to companies operating in other states.

A summary of the capabilities is provided in **Table 0.1**.

TABLE 0.1 APPLICATIONS

Capability	Level of maturity	Relevant infrastructure and services	International competitiveness
Communications, systems and sensors	Potential optical communications capability Networked systems Control systems for autonomous vehicles	UWA ground terminal to support NICT downlink AARNet	Southern hemisphere location highly sought after. WA climate attractive
Microelectronics, networked systems, instrumentation and sensors	Mature capability in Universities, ICRAR and private sector over half of which have a Perth presence or are based in Western Australia	AARNet Innovation Central established by CISCO, Woodside and Data 61	Emerging capability
Space situation awareness	Emerging mature capability in Curtin in conjunction with DSTG and defence industries EOS Services company based in the ACT also has Western Australia relevant capability.	Curtin alliance with DST group and defence industries Advanced Signal Processing Group at Curtin University EOS SLR telescope Desert fireball network Falcon Telescope	Emerging international competitiveness
Space physics, data management and analytics for Astronomy	Mature capability in UWA, Curtin University, ECU and Murdoch University and some companies	Pawsey Super Computer Centre Curtin Institute for Computation	Globally competitive
Radio frequency and interference	Mature capability	UWA undertaking research into radio frequency interference Balance Utilities Solutions has developed capabilities in for radio quiet power solutions	Competitive capabilities

Capability	Level of maturity	Relevant infrastructure and services	International competitiveness
Earth Observation and meteorology - data storage, management, and archiving	Mature capability	Pawsey Supercomputer hosts replica of Digital Earth Australia	Data storage moving to cloud-based solutions to support commercial applications
Earth Observation and meteorology - data processing and technical support	Mature capability	Bureau of Meteorology, Digital Earth Australia, capability in the private sector	Competitive in Australian context and potentially competitive internationally
Autonomous systems and robotics	Emerging capabilities in robotics and existing capability in autonomous systems	Robotics and Autonomous Systems Group, Edith Cowan University Murdoch University Woodside/NASA Collaboration	
Positioning	Mature government and commercial services exist Trimble and Fugro deliver space-based correction services onshore and offshore Leading research capability in Curtin University	Network of reference stations and beacons Internet for some services Curtin multi-GNSS equipment and software. Collaboration with JAXA, IGS, NASA, China and UCAR.	Internationally competitive
Third generation SBAS Augmentation service	Emerging - Test bed research underway	Two SBAS test beds in Western Australia	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.	Several Western Australia companies already provide these services in a range of contexts. Agriculture, mining and offshore petroleum sectors are strong	Competitive with potential competitive advantages in agriculture mining and offshore petroleum operations
Integrated applications	Mature and strong capabilities in agriculture, mining, offshore oil and gas, weather and ocean modelling, vegetation mapping and emergency services. Extensive testing and development of autonomous vehicles and robots.	Intergovernmental relationships and agreements for data access Digital Earth Australia Pawsey Supercomputer NASA Robot at Woodside	Leading edge competitiveness

SOURCE: ACIL ALLEN CONSULTING



4.1 Introduction

Auxiliary services include technical consulting, legal, marketing, policy and regulatory arrangements. Education and training capability in Western Australia is captured under auxiliary services. Some of these services have been discussed in the previous chapters. The upstream and downstream areas of the space industry value chain have generated demand for a range of skilled auxiliary services.

4.2 Legal services

Legal capability in relation to space exists in Curtin, UWA and Edith Cowan universities. Curtin and Edith Cowan university have capability in militarisation of space and formulation of national space strategies.

4.3 Financial services

Financing for space sector activities and infrastructure is derived from government programs in relation to ICRAR, SKA and MRO. Some funding is derived from international space programs such as the ESA Tracking station at New Norcia and Western Australian Space Centre operated by the SSC Space Australia.

4.4 Consulting services

Activities associated with radio astronomy including the SKA activities have generated demand for technical consulting services. For example, Balance Utility Solutions have provided technical advice and feasibility studies for radio quiet power generation. Other companies including NGIS, Ovass Solutions, Think Bottom Up, Kakadu Software, Agrometeorology, GAIA Resources, ASTRON, Ovass, iPaddock, and the Facey Group provide a range of software, technical consulting and in some cases training services.

4.5 Education and outreach

The viability and sustainability of a space industry is heavily dependent on access to a skilled workforce. The prevalence of ground-based facilities in Western Australia, and the future opportunities in automation and remote operation, create a demand for a highly skilled technical workforce. Projects can be large but infrequent, such as the increased demand during the construction phase of a ground station, and the reduced demand required for maintenance. It is important to maintain a capability that can be ramped up during peak demand and allocated to aligned projects in between large projects.

There is a mature education and outreach sector for STEM (Science, Technology, Engineering and Mathematics) education in Western Australia. This has been greatly enhanced by the presence of the SKA. The evolution of mining and ship building into high tech industries is also creating demand for a highly skilled workforce and many of the fundamental skills are similar which allows the transference of staff and the cross training of students.

The four Western Australian universities provide high quality programs across all the disciplines that are essential to a sustainable space industry including but not exclusive to: engineering, spatial sciences, computer science, astronomy, cyber security, mechatronics and material science. This provides a strong innovation pipeline.

South Metropolitan TAFE (SM TAFE) is one of Western Australia's most diverse registered Vocational Training (VET) and Higher Education (HE) Providers, offering over 530 VET qualifications across a wide range of trade, technical and professional disciplines. SM TAFE is a key training provider for high tech and defence industries in areas such as submarines, information technology and aerospace. They have existing courses in Applied Engineering which cover robotics, mechatronics and big data analysis and use virtual reality and simulators to increase the effectiveness of the training. These courses are accredited by Engineers Australia and can be articulated into an undergraduate degree.

SM TAFE has an impressive record of working with defence and industry partners to develop courses that meet their current and future workforce needs. They have existing programs in the automation of heavy automotive, light automotive and mine-site equipment, and the design, prototype and application of sensors for big data analysis that could be further developed to support the needs of the space industry and the use of space technologies in aligned industries.

SM TAFE provides pathway programs which link schools with TAFE, higher education and the defence sector so that current and future defence needs are met and a strategy of attract, train, retain and re-train is adopted to build capability in the sector.

The Curtin Desert Fireball Network has developed a citizen science program, Fireballs in the Sky, that connects the public with the research of the DFN. Through augmented reality, an intuitive interface and sensing technology of a smartphone app, anyone anywhere in the world can recreate their fireball sighting to contribute scientifically useful data. Together with NASA the DFN is expanding to become a Global Fireball Observatory that aims to understand the early workings of the solar system by studying meteorites, fireballs and their pre-Earth orbits. This project was the recipient of the Australian Government Eureka Prize for Innovation in Citizen Science in 2016. Fireballs in the Sky is collaborating further with NASA Outreach and Citizen Science, connecting new communities with this program as the DFN expands globally.

Scitech and Gravity Discovery Centre deliver education and public outreach programs including the CSIRO Pulse@Parkes program. Each of these programs contribute to the development of a scientifically literate community and a skilled future workforce that is aligned with the needs of the space industry.

4.6 Summary

Auxiliary services for Western Australia are summarised in **Table 4.1**.

TABLE 4.1 AUXILIARY SERVICES

Capability	Level of maturity	Relevant infrastructure and arrangements	International competitiveness
Legal, regulatory and marketing	<p>Curtin capability in the assessment of military space programs and the formulation of national space strategy.</p> <p>UWA capability in the use of satellites, drones and remote sensing for monitoring and law enforcement. Also houses international space law capability</p> <p>Edith Cowan has expertise in cyber security law</p>	Established research institutions in Universities	Niche areas of competitiveness
Finance	<p>University Research Funded of ARC Grants</p> <p>ICRAR and SKA funding</p> <p>Some funding for innovation by companies</p>	<p>Some programs that provide finance for innovation include Landgate SPUR</p> <p>Minerals Research Institute of Western Australia</p> <p>Food Agility CRC</p>	<p>Traditional funding roles established</p> <p>Disparate funding for innovation in the private sector</p>
Technical consulting	Mature industries in consulting for construction and maintenance of radio astronomy facilities and low radio noise power generation	<p>Companies include Balance Utilities Solutions, Think Bottom Up, Kakadu Software, Agrometeorology, NGIS, GAIA Resources, ASTRON, Ovass, iPaddock, the Facey Group</p>	<p>Most of these companies would be competitive internationally although some are small and focussed on specific applications</p>
Insurance	N/A	N/A	N/A
Education and training	Many firms and governments provide education and training	<p>North Metropolitan TAFE, Curtin, UWA, Edith Cowan University, Murdoch University, Scitech, Gravity Discovery Centre, Desert Fireball Network</p>	Internationally competitive

SOURCE: ACIL ALLEN CONSULTING



5.1 Cross sectoral interactions

Data from and activities of the space industry are embedded in many sectors of the Western Australian economy as they are Australia wide. This involvement is steadily growing as communications, imagery and position, navigation and timing data is included in sensors, devices and control systems across the economy.

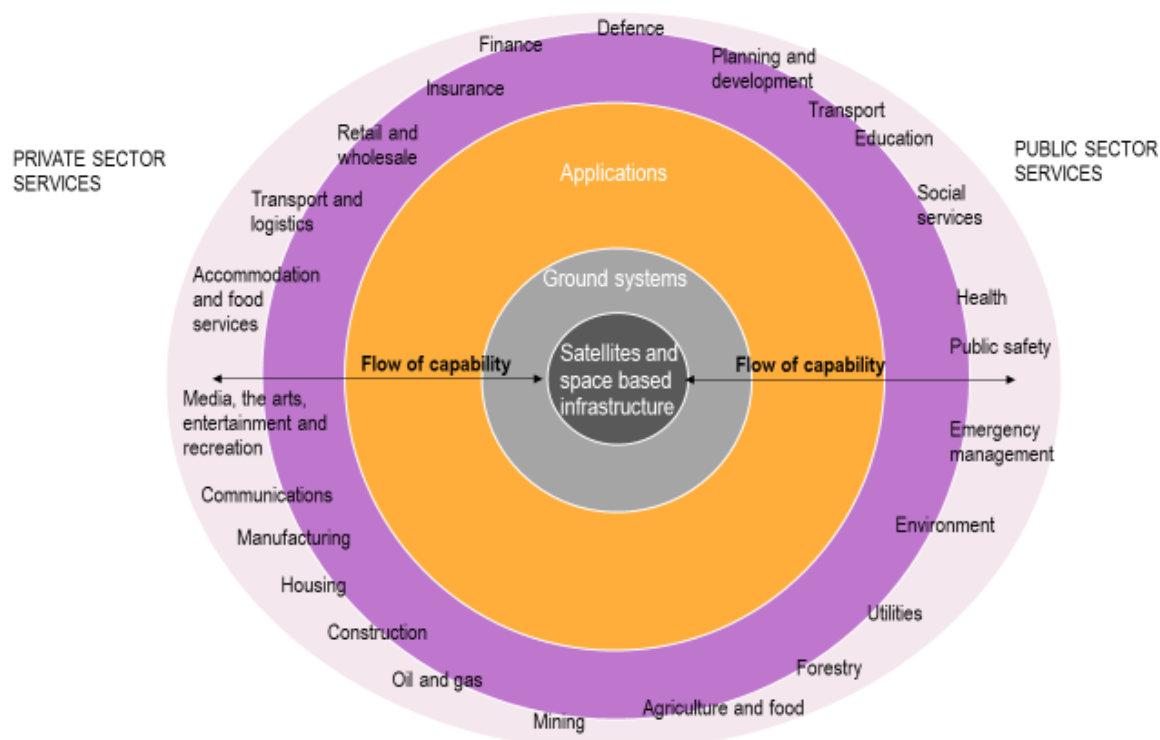
A general illustration of the cross sectoral interactions is provided in **Figure 5.1** below. Space industry capabilities overlap with many Australian industries with the highest share of GDP including services, construction, mining, manufacturing and agriculture (Office of the Chief Economist, 2016).

Knowledge, data and experience flows both ways between the space sector and other sectors of the Western Australian economy. Data from space, communications, Earth Observations from Space, and Position Navigation and Timing (PNT) and capabilities in the space sector also supports applications in many other industries as shown the diagram above, and in Chapter 0 above.

Capability exists in universities, research centres, and the public and private sector organisations that could also be used in the space sector including:

- 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.

FIGURE 5.1 CROSS SECTORAL INTERACTIONS



SOURCE: ACIL ALLEN CONSULTING

5.2 Alignment with other sectors

Table 5.1 sets out an assessment of the alignment between the capabilities in the space industry sector and other sectors of the Western Australian economy. The table shows that these space industry capabilities cross over to most sectors of the Australian economy.

TABLE 5.1 ALIGNMENT WITH OTHER SECTORS OF THE WESTERN AUSTRALIAN ECONOMY

Sector	Current significance	Application/technology	Capability/skills
Agriculture	High Grains industry are early adopters	Precision agriculture, controlled traffic farming, variable rate fertiliser, yield mapping, water and livestock monitoring, weather forecasting	Autonomous vehicles, remote sensing, positioning, data analysis, agricultural engineering, meteorology, analytics
Mining	High	Autonomous vehicles, robotics, vegetation mapping, change and rehabilitation mapping	Robotics, autonomous vehicles, positioning, earth observations from space, remote operations in challenging environments, data analytics

Sector	Current significance	Application/technology	Capability/skills
Offshore oil and gas	High	Rig positioning, weather and sea condition monitoring, marine navigation, shallow water bathymetry, robotics and remote sensing	Robotics, positioning, earth and ocean observations from space, hyperspectral imaging, remote operations in hostile environments, meteorological and ocean monitoring, electronic charts, analytics
Emergency services	High	Mapping, location and addresses, weather and storm monitoring, communications, fire and flood monitoring and prediction	Earth imagery from space, GNSS, communications and meteorology modelling.
Defence	High	Situational awareness, monitoring from space, communications systems	Earth observations from space, positioning, communications, laser ranging.
Transport and logistics	Medium	Location data for logistics, mapping and route optimisation, navigation systems, traffic control systems, intelligent transport systems, autonomous vehicles	Satellite imagery, augmented GNSS, sensors and control systems, optimisation models.
Construction	High	Mapping and location data, autonomous construction vehicles, digital and 3 D mapping, design and construction modelling	Satellite imagery, digital maps, augmented GNSS, sensors and control systems
Surveying and mapping	High	Mapping and location data, 2D and 3D data models, data acquisition	Satellite imagery, digital mapping, GNSS, digital models
Air and sea navigation	High	Maps, high integrity position, electronic chart display systems, landing systems	GNSS, electronic mapping, route optimisation
Planning and development	Medium to high	Mapping and land use analysis, visualisation of proposed infrastructure, public consultation, location and land use analysis, demographic analysis	Satellite imagery, GNSS, data analytics, 3D digital modelling, location based demographic analysis
Health and human services		Land use mapping, epidemiology, location-based disease monitoring, human services, planning primary health care locations, demand mapping	Digitised mapping for epidemiology and decision support for primary health care.
Environmental monitoring	High	Vegetation mapping, landscape change, landscape management, sea level change, weather monitoring	Earth observations from space, Positioning, digital mapping, 2D and 3D modelling
Finance and insurance	Medium	Cybersecurity, timing from GNSS satellites, digital models of the built environment, land use monitoring	Earth observations from space, augmented GNSS, change monitoring, hazard warnings

SOURCE: ACIL ALLEN CONSULTING

The situation in Western Australia differs in two important ways from the rest of Australia. First, the Western Australian Economy is dominated by three important industries: agriculture, mining and offshore oil and gas. Together these industries have a combined value add of \$65.3 billion which represents around 28 per cent of Gross State Product. These industries are heavy users of data and services from space. The task of providing space derived services to these industries has created a specific focus and point of differentiation between companies that supply services to these industries and similar companies elsewhere in Australia.

Second, the existence of significant activity in astronomy, space operations, and positioning activity creates a further focus for science and research coming out of Western Australia that is attracting international space agencies including NASA, ESA and JAXA, and creating a need for many high-tech capabilities including data analytics, microelectronics, radio frequency interference, sensors, remote operations, autonomous vehicles and robotics. There is cross over in some of these areas to

applications in other sectors. The collaboration between Woodside and NASA on robotics is one example.

Further, there are important Defence requirements that are closely linked to the space sector and which generate demand for space-based applications.

This is not to say that the space industry applications in other areas of the Western Australian economy are not important. This is not the case. Applications in emergency services such as Firewatch and in health and human services have been extremely important to the efficiency and effectiveness of many government services. The same can be said for the other industry sectors noted in **Table 5.1** above. However, from the point of view of future growth in the space and spatial sectors and subsequent jobs, those capabilities focussing on the challenges in the agriculture, mining and offshore oil and gas sectors are likely to be able to develop capabilities that could be a point of differentiation when competing in national and international markets.

ACIL Allen's earlier report on space industry capability for Australia noted that the 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 security⁵ have greater potential to benefit from space industry capabilities than the existing major economic sectors.

From a Western Australian perspective, the important areas of focus are space-based applications in:

- science
- operations
- astronomy
- defence
- agriculture
- mining
- offshore oil and gas operations

In general terms it has been estimated that around 80 per cent of the jobs in the space supply chain arise in the applications of space sourced data in other industries. Not to down play the importance of space science however, as in Western Australia there is a unique opportunity to flow the capabilities both ways.

⁵ See: <https://industry.gov.au/Office-of-the-Chief-Economist/Publications/AustralianIndustryReport/assets/Australian-Industry-Report-2016.pdf>



6.1 Comparative and competitive advantage

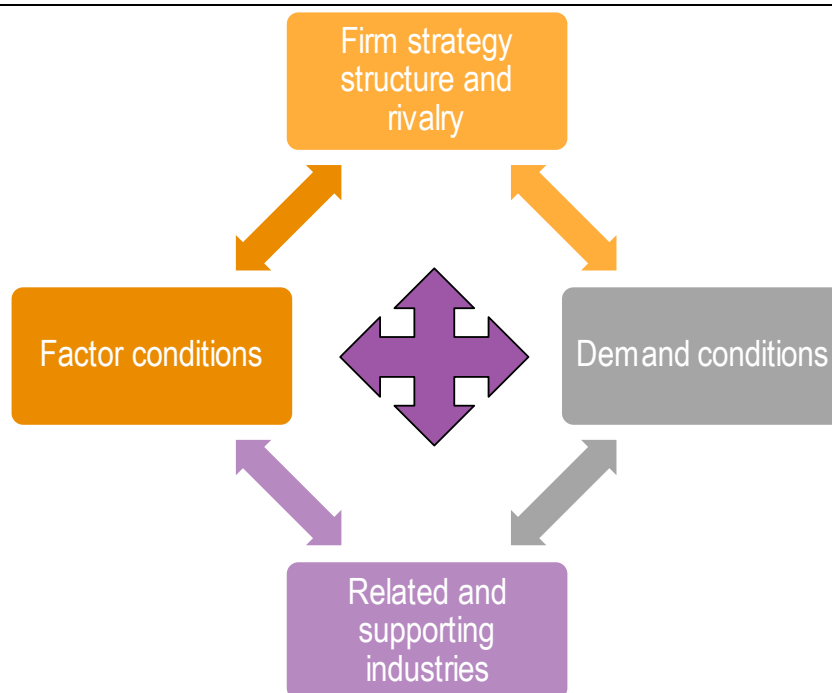
Comparative and competitive advantage are different concepts. Comparative advantage relates to the natural endowments that a country or region has that favour certain economic activities over other activities. Comparative advantage may be related to land, location, natural resources, labour and the quality of its institutions. In early economic literature comparative advantage was, and to some extent still is, the source of difference in industry structures between different nations.

Competitive advantage is different. It is the advantage that organisations create by means of their operations, differentiated or specialised products and services or cost competition, innovation, market strategies or alliances. Competitive advantage generally builds on comparative advantage but can also overcome comparative disadvantage in some markets.

Competitive advantage of firms in a geographic region is a significant contributor to the success of that region's economy. However, this success depends on several interacting factors. This was outlined by Professor Michael Porter in his book *The Competitive Advantage of Nations* (Porter, 1990). Porter cited four factors that determine sustained competitive advantage of a geographic region as shown in **Figure 6.1** below. These factors and their significance are:

- firm strategy, structure and rivalry
 - markets are dynamic and direct competition encourages firms to increase productivity and innovation
- demand conditions
 - the nature of demand of customers in the local region creates pressure on firms to constantly improve their competitiveness through innovation, quality products and services or cost savings
- related supporting industries
 - spatial proximity of related upstream and downstream industries facilitates promotes continuous exchange of ideas and innovation
- factor conditions
 - in earlier literature, factor conditions reflected comparative advantage. However specialised factor conditions such as skilled labour, capital, infrastructure and institutions (including research institutions) are more important to sustained competitive advantage.

FIGURE 6.1 DETERMINANTS OF THE COMPETITIVE ADVANTAGE OF A NATION OR GEOGRAPHIC REGION



Note: Government policies influence each of these four characteristics

SOURCE: (PORTER, 1990)

Understanding the comparative and competitive advantages that the Western Australian Space Industry enjoys is important to identifying which areas of growth and jobs might emerge in Western Australia with the right policies and road map.

However, the interaction between these factors will be important in identifying those industry areas that are likely to be competitive nationally and internationally and will also be important in identifying those areas that are likely to build competitiveness and hence build the space sector economy and jobs in Western Australia.

6.2 Comparative advantage

Western Australia has several geographical characteristics that differ to most other parts of Australia and indeed the world.

Western Australia's geographic location and sparse population provides extensive areas with minimal electromagnetic interference and ideal dry atmospheric conditions. This makes Western Australia an attractive setting for major space projects. This is one of the underlying advantages that has attracted space and astronomy infrastructure and activities including the SKA and several space observation facilities. With sparsely populated regions it has been possible to establish the Australian Radio Quiet Zone Western Australia (ARQZWA) in the mid-west Region of the State centred around the Murchison Radio Astronomy Observatory (MRO).

Western Australia's southern hemisphere location and longitude are critical for the establishment of networks that require contiguous global coverage of space assets. The establishment of several new civilian and military space facilities in Western Australia now help to create a hub for space science and technology.

Western Australia's southern latitude and positioning between Europe and North American and at the foot of Asia places it in an ideal position to track launches from most launch sites around the world.

Radio quiet zone



SOURCE:
[HTTP://WWW.SKA.GOV.AU/OBSERVATORY/PUBLISHINGIMAGES/P1070164.JPG](http://www.ska.gov.au/observatory/PUBLISHINGIMAGES/P1070164.JPG)

Western Australia also sits under a confluence of GNSS constellations. Some 35 GNSS satellites pass over Western Australia giving it access to most of the GNSS satellite constellations flying globally. This is a higher number than in the eastern states.

The characteristics of operating in Western Australia help create important comparative advantages for companies servicing remote operations, remote sensing and autonomous vehicles in remote settings in comparison to some of the other states and potentially internationally.

6.3 Competitive advantage

Competitive advantage builds on the four factors identified in Section 6.1 above. It is first useful to review the characteristics of Western Australia.

6.3.1 Firm strategy structure and rivalry

During research for this report ACIL Allen identified 91 companies/private organisations with business activities in the space industry sector.

Of these around 68 (74 per cent) have a presence in Western Australia. Some of these companies are international companies or subsidiaries of international companies such as Lockheed Martin, Raytheon Australia, Fugro, Trimble, CISCO, Top Con, L3 Oceana and Amazon.

Others are small to medium enterprises such as NGIS Australia, Gaia Resources, Picosat Systems, Sky and Space Global, Takor Group, ThinkBottomUp, Romtek, AgroMeteorology Balance Utility Solutions and Go Co.

A total of 55 Australian companies were identified as having business activities in the space industry sector. Of these, a total of 41 companies (75 per cent) had a presence in Perth.

TABLE 6.1 COMPANIES IN THE SPACE INDUSTRY SECTOR IN WESTERN AUSTRALIA

Companies with a presence in the space sector in Western Australia	Number	Share
Total number of companies	94	
Number of companies with a presence in Western Australia	67	71%
Total number of Australian owned companies	55	
Number of Australian owned companies with a presence in Western Australia	41	75%

Note: Includes companies with a component of their activities involved in the space sector in one way or another

SOURCE: ACIL ALLEN CONSULTING CONSULTATIONS AND RESEARCH

The larger international companies are strong competitors in Australia. This includes companies such as Lockheed Martin, Raytheon, Fugro and Trimble. The larger Australian companies are also highly competitive. Woodside, Rio Tinto and Wesfarmers, for example, are at the forefront of utilising space related technologies in their businesses, although these technologies are not core business but rather tools that they develop and use in pursuit of their business objectives.

The smaller Australian companies and SMEs are in different stages of developing their competitive advantage but have the potential to build globally competitive capabilities in niche areas of the use and application of space sourced data and space technologies.

Some of the Australian companies consulted reported that revenues from the markets in which they operate were variable. For example, some of the companies reported that revenues from the mining sector fell after the collapse of commodity prices resulting in some of their business areas drying up. However most had been able to diversify into alternative product and service lines to continue business. Nevertheless, volatility in these markets made it hard to maintain sufficient working capital to undertake the research and development they need to pursue emerging markets. Some note that most of the research budgets available from government programs are targeted to research bodies

and not companies. They were not arguing that research institutions should not be funded but that there was a gap in funding at the pre-competitive stage of product development for businesses.

The business models for research bodies and for companies are different. Research bodies tend to focus on longer term science and technology development. Commercial research is more generally focused on product trialling and product development with a commercial return horizon sometimes as short as one year.

There are some government programs that focus on this research “gap”. The programs of Landgate SPUR and the Minerals Research Institute of Western Australia are seeking to help companies with some funding to trial and develop commercial products in the pre-competitive stage of commercial research and development.

SPUR for example seeks to nurture a pipeline of partnerships, investment opportunities and support for emerging Western Australian based location technology businesses.

Innovation Central seeks to feed technology from the data and science that is associated with the SKA to industry. This is to provide connectivity to support networking, security and collaboration. Since opening in 2016 the centre has engaged with over 200 small, medium and large companies and 30 government agencies and departments. It has established over 70 projects in the fields of robotics, automation, mining, oil and gas, agriculture and facilities management.

The METS/NERA hub being established aims to support pre-competitive research into applications in the mining sector. As mining becomes increasingly automated digital jobs will be created, however these digital jobs can operate anywhere in the world.

Its aim is to promote collaboration between science research and industry to build capability in these skills so that as far as possible companies in Western Australia can realise some of the spin-offs from these technological developments in the mining sector.

Other hubs and collaborations also operate in Western Australia. These include Space cubed, Flux, Unearthed and Space Hub. These are start-up accelerators and are reported to be in a growth phase. This may also reflect a migration to these accelerators following the downturn in the Western Australia economy following the fall in commodity prices. Space cubed is a general accelerator hub, Flux is an agricultural accelerator and Unearthed is a mining and energy accelerator. Space Hub Perth is a facility created to foster a coordinated local space industry in Western Australia and foster communications and consultations between interested companies and individuals.

Not all companies consulted support the hub concept. Some suggested that they were of more interest to academics than companies examining commercial opportunities.

6.3.2 Factor conditions

The underlying comparative advantages that space related industries enjoy in Australia have been discussed in Section 6.2 above. However, factor conditions include more than just geographic and locational advantages. Development of specialist skills, the quality of education, the quality of research institutions, collaboration at the pre-competitive stage and government policy are important to sustained competitive advantage.

Research institutions

The research institutions in the Universities in Western Australia, CSIRO and the astronomical programs and facilities, under the oversight of ICRAR, at MRO and associated activities associated with the SKA such as the Australia SKA Industry Consortium (ASKAIC) are important to sustainment of competitive advantage in the space industry sector.

The activities of these research institutions are important economic activities. The institutions and programs themselves may not be the largest employers of professional and technical staff but they will provide training and skills that could be transferable to industry. It is the transfer of these skills and capabilities to industry that is of interest for the major source of future employment.

The Universities are also examining potential to work with the private sector where opportunities arise. For example, Curtin University has expertise in asset management in extractive industries such as

corrosion engineering, materials and characterisation science that could be transferred to space related industries.

UWA advances research areas including cryogenic sapphire oscillators, laser calibration for multiple dishes, atomic clock and timing, microelectronics and advanced sensing technologies. The University has a proactive innovation and industry engagement program.

Communications infrastructure

Communications infrastructure was raised during consultations as being a major concern for the commercial use and application of space derived data in areas remote from the main centres. This was reported to be an issue in the application of these technologies in agriculture and mining as well as in the science field.

The Australian Academic and Research Network (AARNet) interconnects Australian researchers with data intensive resources such as telescopes, storage and computational facilities, and the global research community. In Western Australia the network connects research organisations including the universities, the Pawsey Centre and the MRO via optical fibre cable (see **Figure 6.2**).

FIGURE 6.2 AARNET



SOURCE: https://www.aarnet.edu.au/images/uploads/resources/aarnet_national_network_map_082017.pdf SOURCED ON 10 MARCH 2018

During consultations it was suggested that expanding this network would enhance economic benefits and employment opportunities by increasing the capacity, speed and reliability of connection in Western Australia.

Expanding the network is expected to attract commercial and government organisations to Western Australia in industries including communications, defence, space data and research. To realise the

economic benefit, it is also important to ensure that commercial companies can access this infrastructure.

The proposed data link would enable:

- the establishment of Western Australia as the Southern Hemisphere hub for geodesy and radio astronomy research and for space science missions
- the establishment of an ultra-precise timing link between the most accurate atomic clock in the Southern Hemisphere, the world's most productive satellite laser ranging facility and Australia's most western radio interferometry antenna.

From the point of view of business and employment opportunities, development of Western Australia as a space hub is a positive development. The space sector may not be a large employer, but space industry activities will generate the need for service providers such as software developers, data analysts and contractors to support the space activities. As discussed above space activities will also build skills that could be transferable to the private sector.

AARNet is not available to commercial users. This could be an issue worth exploring should commercial opportunities in data analytics arise from either space related activities or space applications.

Computation Infrastructure

The Pawsey Supercomputing Centre at Kensington is a collaboration between CSIRO, Curtin University, UWA, Edith Cowan University, Murdoch University and the Western Australia Government. It was established to support research related to the SKA.

It operates in collaboration with the National Computing Institute at the Australian National University. The facility is not at this stage open to use by commercial enterprises, but a commercial model is under consideration. This would require co-investment from the private sector for an expansion in capacity and the establishment of commercial services and cyber security protocols. It could include commercial data storage facilities and would need ISO accreditation.

A commercial model would require access to adequate infrastructure including communications. The AARNet is currently not available to companies and this may need to be addressed if a commercial model is to be established.

Data analytics is a growing discipline and many companies are now applying data analytics to their operations. This is increasingly so in complex mining and petroleum operations in Western Australia for example. Traditional simulation is moving towards machine learning and artificial intelligence. Networked sensors are used to collect data, but many companies do not have the capacity to extract the full intelligence from these sensors.

Not all data analytics require super computers. There are developments to access data and the analytical capacity through the cloud. Digital Earth Australia is moving down this path.

Having said that the Pawsey Supercomputer Centre is important infrastructure that has the potential to support sustainable competitive advantage for the space research industry and the commercial world in Western Australia.

6.3.3 Related and supporting industries

As noted in Section 6.1, spatial proximity of related upstream and downstream industries facilitates continuous exchange of ideas and innovation. There is significant potential for such an exchange of ideas and innovation between the space and astronomy research activities in Western Australia and the commercial organisations that either service them or draw on data and services from space operations to develop systems and services for industry and government applications in Western Australia.

Such interactions between related and supporting industries is very important to the development of sustainable competitive advantages for Western Australian companies, particularly those operating in the space applications area.

There are many examples. One is the Picosat System mentioned earlier in this report. The company is currently working with UWA and ICRAR to identify applications for micro satellites. They are using a commercial off the shelf demonstrator with an optical two mega pixel camera for imagery. The project involves some optimisation of software. They have engaged in the broader space and software community through the Space Hub meeting group. The company reported that technology development is capital intensive and testing and evaluation is a challenge to mature and commercialise the technology. They are hoping to draw on university facilities to undertake some of this testing.

Another example is NGIS Australia where NGIS developed software for vegetation monitoring and analysis. The rights to the software was purchased by Wesfarmers and is now marketed as Decipher.

Poseidon Scientific Instruments developed and delivered production ready receivers for ICRAR. The work was internationally recognised as breakthrough technology. While Poseidon was subsequently acquired by Raytheon, this example nevertheless highlights the potential for related and supporting industries to develop skills and innovation that can be transferred to other commercial applications both in Western Australia and more widely.

Clearly there are significant opportunities for Western Australian based companies to develop special skills and capabilities based on the demand for services by both the upstream space sector and industry in Western Australia that could build sustainable competitive advantage in certain markets.

6.3.4 Demand conditions

The space industry is a global industry and firms operating in that industry can compete globally or nationally. With the move to automation and remote monitoring and control it can be expected that some on site operational jobs will disappear while others in data analytics, remote sensing, autonomous vehicles and robotics will be created. The challenge with this scenario is that some of those skills can be provided from anywhere in Australia and sometimes from anywhere in the world.

The demand conditions in Western Australia are extremely important to the development of sustainable competitive industries. They create the markets in which companies can focus their business strategies, develop their capabilities and skills and progress innovation to meet the needs of Western Australian space and industry challenges.

There are four areas where demand conditions create opportunities for Western Australian based companies. These are: space activities and research, defence, agriculture, mining and offshore petroleum operations.

The opportunities in these areas have been discussed in previous chapters pointing out that they provide demand conditions that are dominant in Western Australia and therefore create a point of differentiation for companies servicing these markets.

Other sectors

There are other sectors that also utilise spatial and space information and services that have been developed by government and industry in Western Australia. These includes emergency services, traffic management, logistics, mapping of health data, surveying and mapping, planning and construction. Landgate and Western Australian based companies have developed many products and services that have had national application. However, Western Australian companies face similar demand conditions as in other states and territories in Australia. They therefore do not have the benefit of developing products that companies operating in the other parts of Australia have. It will be more difficult for them to develop a differentiation based on demand conditions alone.

6.4 Key findings

Competitive advantage is built on several factors, not just the nature and strategies of the firms operating in the state. The nature of the market in Western Australia, the factor conditions including infrastructure and special skills and related and supporting industries located in the state are also important to the development of sustainable competitive advantage for Western Australian businesses.

From this analysis the most prospective areas for growth and jobs would appear to be:

- space research and operations
- defence space requirements
- agriculture
- mining
- oil and gas

There will be other areas that the local industry can and is pursuing. However, the specific demand conditions and the space related infrastructure that exists in Western Australia suggests that the above areas are likely to be the most prospective for business growth and employment. Evidence from our consultations for this report suggests that industry applications (the downstream space sector) are likely to provide around 80 per cent of the jobs in future.

This, however, does not imply that space related activities in the universities, the upstream space sector, astronomy and activities related to space activities in Western Australia are not important. They are critical to building skills and capacity that will benefit the total sector including applications. There is also potential for transfer of skills and innovations both ways between the space industry and industry in Western Australia as well as for the rest of Australia.

8

OPPORTUNITIES
FOR GROWTH

7.1 Introduction

The previous chapters lead ACIL Allen to the conclusion that the main opportunities for growth lie predominantly in the areas of application that service the space sector itself, defence space needs, agriculture, mining and petroleum sectors of the Western Australia economy. This is where Western Australian firms have the greatest potential to develop a sustainable competitive advantage over firms elsewhere in Australia and overseas.

FIGURE 7.1 PRIORITY AREAS FOR FUTURE GROWTH IN THE SPACE INDUSTRY SECTOR IN WESTERN AUSTRALIA



SOURCE: ACIL ALLEN CONSULTING

There are important linkages between these sectors and transferrable skills and capabilities that flow both ways between the sectors.

It is most likely that the greatest number of jobs would be created in the space applications areas than in the upstream space activities. However, space research, operations and astronomy activities in Western Australia are as important to building a sustainable competitive advantage as are the downstream applications that can be derived from the use and application of space sourced data.

7.2 Research

There are significant opportunities for research institutions to develop both upstream and downstream technologies and applications to service the needs of the space industry in Western Australia. The universities and CSIRO have established expertise, facilities and collaboration in space industry sectors including:

- astronomy and planetary science
- defence industry research
- space situational awareness
- instrumentation and advanced detector development
- remote operation in extreme environments
- satellite communications research
- earth observations from space and advanced signal processing
- global and regional satellite navigation systems
- robotics and autonomous systems
- cyber security computation and big data

The universities and CSIRO along with ICRAR are leaders in many of these fields and consolidation of these work areas are important to further building Western Australia's space activities and the upstream space businesses.

Communications infrastructure is important to the space industry as well as to research. The AARNet communications link between Perth based research institutions, the Pawsey Super Computing Centre and the MRO is an important supporting infrastructure.

The Pawsey Super Computing Centre is an important facility that could provide access to the commercial sector in the longer term. Data analytics is a growing field and has applications in the mining and petroleum sectors in Western Australia. However, access to the AARNet would probably be required if this were to occur.

Some aspects of data analysis may in future be undertaken through cloud services reducing the need for full access to Super Computing facilities.

7.3 Space industry activities

Western Australia's key capabilities in space activities include:

- ground station capability (including launch tracking, deep space communication, satellite communication, Earth Observation and PNT)
- laser communications capabilities
- space situational awareness – optical, near infrared and radio facilities capable of finding and monitoring of low Earth orbit space debris and incoming meteorites
- GNSS and GNSS correction services

The astronomical telescopes at Murchison, Yarragadee, the Perth observatory, the Falcon Telescope at Yeal and the Desert Fireball Network are important assets with some growth potential.

The involvement of ESA in the tracking station at New Norcia and the Swedish Space Corporation at Yarragadee are significant investments for Western Australian ground stations along with several other ground stations including the Optus Earth Station at Lockridge for satellite communications and the Geoscience Australia satellite laser ranging station at Yarragadee.

There is potential for further consolidation of space activities in Western Australia, subject to ongoing development of communications infrastructure and the Western Australian government deepening contracts with national and international space institutions. This is important for two reasons:

- It keeps Western Australian institutions engaged with international activities.
- It ensures that those areas where Western Australia can offer advantages to the space sector are considered when the Australian Space Agency is established and rolls out programs to implement its agenda.

7.4 Defence

There are expected to be opportunities in C-band radar, SST, EOS and Satellite Laser Ranging and opportunities for construction and maintenance. The latter are likely to be only for the prime defence contractors.

The opportunities are currently being evaluated though research commissioned by the Western Australian Defence Advocate. This report was not available at the time of writing this report. However, the above are areas of opportunity for firms in Western Australia where applications are to be undertaken in the state.

There are not likely to be significant jobs created from the Defence Space program as many of the contracts are likely to go to established prime contractors to Defence who will service their needs from elsewhere in Australia or potentially overseas. However, there will be opportunities for services in ground station construction and satellite observation facilities that could be open to Western Australian based contractors.

7.5 Agriculture

The growth in precision farming in Western Australia and the expansion of the use of applications and services based on data derived from space creates ongoing opportunities for application developers and service companies in Western Australia.

As outlined in this report there are at least nine companies in Western Australia providing services to the agricultural sector. While one is a large international firm with operations in Perth and the other a major Perth based Australian company, the others are Australian owned small to medium enterprises, some of whom have markets in Australia and overseas.

The challenge for the small to medium enterprises is the continuity of work and volatility of the markets in which they operate. Some have diversified markets which helps manage volatility in earnings from market segments. However, consultations indicated that the main challenge they face is trialling and testing new products and services.

Commercial products have a short return requirement that is sometimes as low as one year. University research normally focuses on longer term timeframes with little scope for testing and trialling products with shorter time frames for commercialisation.

There are organisations that seek to address this gap. Two examples are Landgate's SPUR initiative and the Farm Agility CRC. SPUR supports a pipeline of partnership, investment opportunities and support for emerging Western Australian based location technology businesses. SPUR activities are aimed at collaboration, stimulation and acceleration. Agricultural research projects are eligible for SPUR assistance.

The Farm Agility CRC also fosters collaboration between research institutions and industry in research and testing of research and innovation. These and similar institutions are important to the industrialisation and trialling of research and innovation.

The Rural Research and Development Corporations are also collaborating in the future of digital agriculture and this should be a source of funding for applied research in this area.

7.6 Mining and oil and gas

Mining and oil and gas is a further opportunity for growth in Western Australia. The high utilisation of space relevant technologies in some of the larger mining companies creates opportunities for Western Australian firms to provide services to the mining and oil and gas sectors.

These sectors have been early adopters of autonomous mining vehicles, remote sensing and remote operations, robotics and data analytics. Companies such as Woodside, Rio Tinto, BHP and the Fortescue Metals Group are understood to have adopted many of these technologies. Application of robotics, remote operations, data analytics and ultimately artificial intelligence are potential technologies for the mining industry in the near term.

The level of adoption in the smaller mining companies is lower. The Mining Research Institute of Western Australia is an important source of funding for research and development particularly for the smaller companies.

Another collaboration between the Mining and Energy Technical Services (METS) and National Energy and Resources Australia (NERA) will seek to develop skills used by the industry. This includes data scientists and investment in capability that will deliver the skills that can be used by industry in secure remote locations. As plants are automated digital jobs will be created. These skills can operate anywhere in the world. Therefore, there is a need to develop skills management.

Some of the innovations could involve two-way transfer of skills between the upstream space industry sector and industry. The Woodside collaboration with NASA on robotics is an example of potential two-way technology transfer between these respective sectors.

7.7 Issues and recommendations

7.7.1 Raising the profile of the WA space industry sector

Until recently Australia's capabilities in the space industry were not as widely recognised internationally as other countries. Western Australia has always been recognised for its contribution to astronomy and space science but activities in space related applications including precision farming, mining and robotics have not been as prominent.

Government should raise the profile of the State's strengths in space science, operations and applications particularly in agriculture, mining and robotics. This could commence with the Australian Space Agency when established but should include engagement with national and international agencies and relevant industry organisations.

The Government should consider the possibility of joining the existing collaboration between South Australia, the ACT and the Northern Territory to promote coordination and cooperation of the different competitive strengths.

7.7.2 Strengthening existing capability

Western Australia should leverage its geographic advantage by strengthening infrastructure and building capability in areas such as GNSS, Earth Observation, optical communication, deep space tracking and space situational awareness.

Western Australia should build on the investment in research infrastructure such as the Pawsey Centre and AARNet. The case for making these facilities accessible to industry for commercial applications should be evaluated. Establishing commercial operational procedures and broadband connectivity for companies should be considered.

The Western Australian Government should evaluate opportunities for investment in technical facilities that will stimulate commercial activities in Western Australia, such as compliance testing for the SKA, with a view to these facilities establishing a capability to support other commercial projects.

Opportunities for operating and/or running space infrastructure in Western Australia should, where feasible, be offered to the private sector to help local industry develop and grow its business base around space industry activities.

7.7.3 Priority areas

This report notes that the major drivers of jobs and economic growth will lie in the private sector with focus on applications in defence, agriculture, mining and offshore oil and gas.

The competitive strengths of the space industry and applications sector in remote operations of sophisticated systems should be supported by aligning the activities of government, industry, research institutions and research funding.

Government and industry should build on existing capability and international relationships and seek projects that will establish capability in Western Australia and support technology and knowledge transfer in line with Western Australian priorities.

Government should review the availability and adequacy of funding to the private sector for pre-competitive research, development and demonstration of applications, with emphasis on those servicing agriculture, mining, offshore operations and remote operations and robotics.

7.7.4 Collaboration

It will be important for Western Australia to have strong linkages nationally and internationally to ensure that their interests are considered when the new Australian Space Agency is developing national policies and programs. National linkages are also important to promote alignment with the government agencies with responsibility for space activities including Geoscience Australia and CSIRO.

It will be important for institutions to maintain contact with international partners to promote the expansion of international involvement in space facilities and programs in Western Australia. This should be done with the aim of building national capability as the space industry in Australia is not large enough to withstand international competition.

There are several organisations established to foster collaboration, stimulation of research and acceleration of innovation. Important established arrangements include:

- Australian Square Kilometre Array Industry Consortium (ASKAIC)
- Innovation Central
- NASA Solar System Exploration Research Virtual Institute (SSERVI)
- International Centre for Radio Astronomy Research (ICRAR)

There is a divergence of business models between research into space science conducted by universities and space agencies and research undertaken by companies for development of commercial products and services. Government should investigate the effectiveness of collaboration between the research institutions and industry, including the effectiveness of existing collaborative arrangements, with a view to improving the development of new products and services by the private sector in Western Australia.

Noting that Western Australian institutions and companies already have expertise in cyber security and space situational awareness, the Western Australian Government should encourage increased collaboration between civil and defense space activities.

7.7.5 Education

Building skills in the emerging technologies of remote sensing, data management and analytics, cyber security, GNSS technologies and control systems, and robotics will be important. There is potential for the transfer of skills between the space sector and industry, notably in the three industry priority areas. The universities and South Metropolitan TAFE have high quality existing programs and the ability to develop new program in consultation with industries that integrate disciplines and address identified industry needs.

The adequacy of existing professional and technical training programs should be reviewed against the needs of the space industry and the applications areas particularly with respect to the priority areas of competitive advantage identified in this report.



GLOSSARY OF TERMS

AAO	Australian Astronomical Observatory
AARNet	Australia's Academic and Research Network
ACES	Atomic Clocks Ensemble in Space
ADF	Australian Defence Force
AMSA	Australian Maritime Safety Authority
ARQZWA	Australian Radio Quiet Zone WA
ASKAIC	Australian SKA Industry Consortium
ASKAP	Australian SKA Pathfinder
AWS	Amazon Web Services
CASDA	CSIRO ASKAP Science Data Archive
CASS	CSIRO Astronomy and Space Science
CBIS	CSIRO Business and Infrastructure Services
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSP	Central Signal Processor
DFN	Desert Fireball Network
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
EDGES	Experiment to Detect the Global Epoch of Reionization Signature
EOS	Electro Optic Systems
ESA	European Space Agency
GNSS	Global Navigation Satellite Systems
ICRAR	International Centre for Radio Astronomy Research
ILUA	Indigenous Land Use Agreement

JAXA	Japanese Aerospace Exploration Agency
LFAA	Low Frequency Aperture Array
LIGO	Laser Interferometer Gravitational-Wave Observatory
METS	Mining, Equipment, Technology and Services
MOBLAS	NASA international laser ranging service
MRIWA	Mineral Research Institute of Western Australian
MRO	Murchison Radio-astronomy Observatory
MWA	Murchison Widefield Array
NERA	National Energy Resources Australia
NICT	National Institute for Communications and Information Technology (Japan)
SADT	SKA Signal and Data Transport
SDP	Science Data Processor
SLR	Satellite Laser Ranging
SSA	Space Situation Awareness
SSC	Swedish Space Corporation
SST	Space Surveillance Telescope
TRDRSS	Tracking Data and Relay Satellite Systems
TT&C	Telemetry, tracking and control
TTPO	ESA Technology Transfer Project Office
VLBI	Very Long Baseline interferometry
WASC	Western Australian Space Centre
WASTAC	Western Australian Satellite Technology and Applications Consortium



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The terms of reference for this report are to report on the following items:

1. Existing space industry capability in Western Australia by category as established by the OECD and refined by the UK Space Agency (see Attachment 1).
2. Alignment with other sectors including defence, cyber security, geospatial data acquisition and management, 'big data' processing, automation and remote/hazardous operations.
3. Western Australia's comparative and competitive advantages including geography, research, technical capabilities and existing partnerships and relationships.
4. Opportunities for growth in industry, jobs, the research sector and training to support development of a sovereign space capability



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 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 (London Economics, 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'.



C.1 Telescopes

- Murchison Radio-astronomy Observatory (MRO), Murchison
- Australian Square Kilometre Array Pathfinder (ASKAP)
- Murchison Widefield Array (MWA)
- University of Tasmania Very Long Baseline Interferometry (VLBI) radio telescope at the Western Australian Space Centre at Yarragadee
- Perth Observatory, Bickley
- Falcon Telescope, Yeal
- Desert Fireball Network (DFN), distributed nationally.

C.2 Ground Stations

- ESA Tracking Station at New Norcia (Deep Space Communication)
- Optus Earth Station, Lockridge (Satellite Communication)
- Swedish Space Corporation, Western Australia Space Centre, Yarragadee (Satellite Communication)
- Perth International Telecommunications Centre, Lansdale
- Geoscience Australia MOBILAS 5 Satellite Laser Ranging station, Yarragadee
- Western Australian Satellite Technology and Applications Consortium (WASTAC) L-band antenna at Curtin, L & X-band at Murdoch University
- Learmonth Solar Observatory, Learmonth
- AMSA MEOSAR satellite ground stations, Mingenew
- EOS Space Systems Satellite Laser Ranging Telescope, Learmonth

C.3 Other Support Infrastructure

- Pawsey Supercomputing Centre, Kensington

C.4 Defence Facilities

- Naval Communication Station Harold E. Holt, Exmouth
- Jindalee Operational Radio Network (JORN), Laverton and Leonora
- Australian Defence Satellite Communications Station, Karna

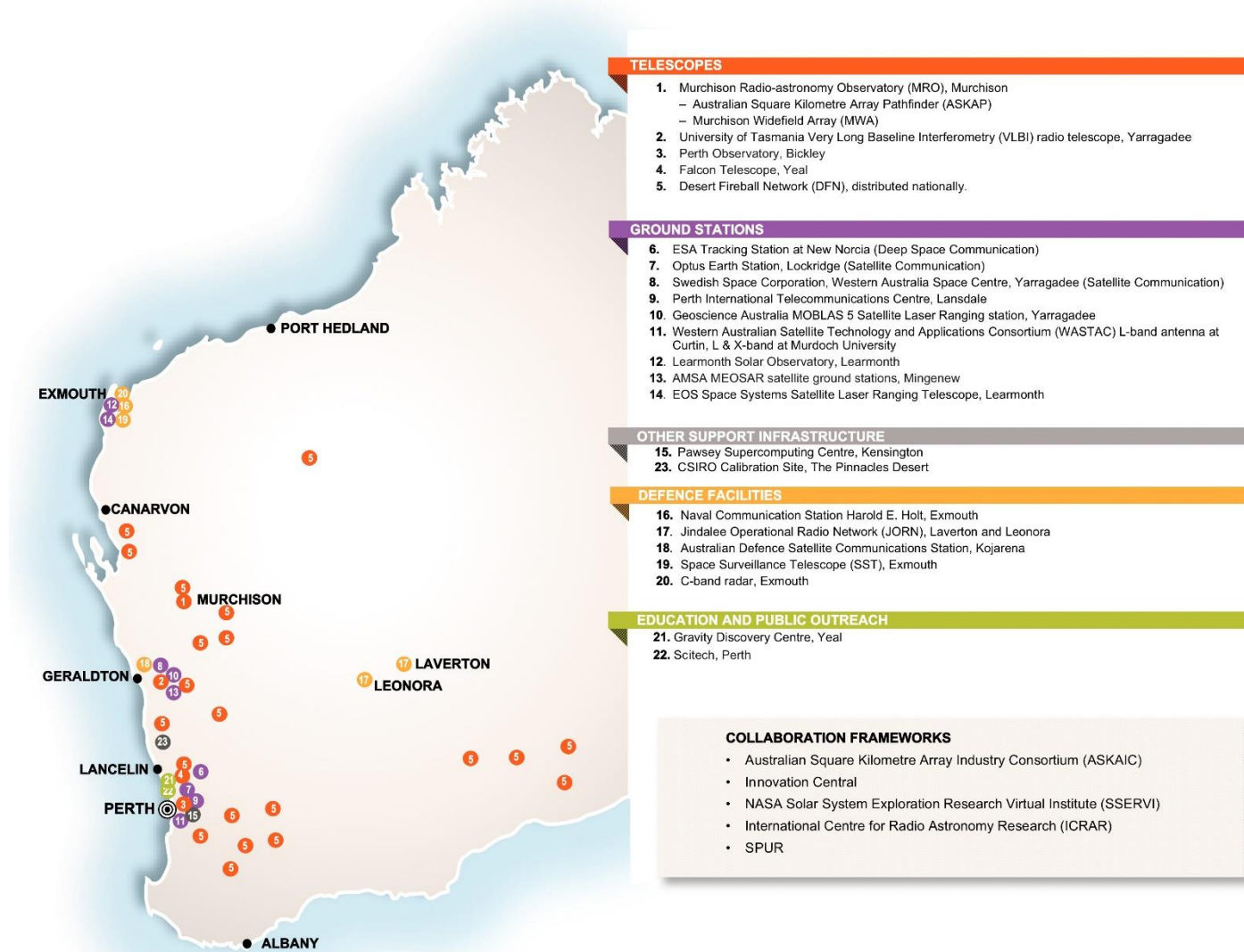
- Space Surveillance Telescope (SST), Exmouth
- C-band radar, Exmouth

C.5 Collaboration frameworks

- Australian Square Kilometre Array Industry Consortium (ASKAIC)
- Innovation Central
- NASA Solar System Exploration Research Virtual Institute (SSERVI)
- International Centre for Radio Astronomy Research (ICRAR)
- Mining Research Institute WA
- Landgate SPUR
-

C.6 Education and Public Outreach

- Gravity Discovery Centre, Yeal
- Scitech, Perth

FIGURE C.1 INFRASTRUCTURE

SOURCE:

**TABLE D.1** ORGANISATIONS CONSULTED

Organisations consulted	University/Government/ Education	Collaboration	Company
Agro Meteorology			1
Astron		1	
Centre for Defence Industry Capability			1
CISCO			1
Wheeler & Associates			1
CRCSI (WA Office)		1	
CRCSI (GNSS test bed)	1		
CSIRO (Industry engagement)	1		
Curtin University Earth and Planetary Science	1		
Curtin University Institute for computation	1		
Curtin University Institute for Computation	1		
Curtin University Research Office, Energy and Space Initiatives	1		
Edith Cowan University Defence research and engagement)	1		
Edith Cowan University (Cyber Security)	1		
EOS Space Systems			1
Fast Wave			1
Food agility CRC		1	
ICRAR (past director)		1	
Fugro			1
Gaia Resources			1
ICRAR (Director)		1	
ICRAR (Innovation and industry engagement)		1	
iPaddock			1
John Deere			1

Organisations consulted	University/Government/ Education	Collaboration	Company
Landgate (CEO)		1	
Landgate (SPUR)		1	
IL3 Oceana			1
Lockheed Martin			1
NGIS			1
Nexial			1
Ovass			1
Pawsey Centre	1		
Picosat Systems			1
Sky and Space Global			1
Spookfish			1
South Metro TAFE	1		
SSC Space Australia			1
Thales			1
Topcon			1
Trimble			1
UWA Innovation and Industry Engagement	1		
WA Chief Defence Officer			1
Woodside			1
Total number interviewed = 43	13	6	24
Note: In some cases, more than one business unit was interviewed in an organisation			
SOURCE: ACIL ALLEN CONSULTING			

**TABLE E.1** FIRMS WITH THE SPACE INDUSTRY RELATED ACTIVITIES IN WESTERN AUSTRALIA

Company	Description	WA presence	Business description
AAM	National company with WA presence	Yes	Geospatial services
Agro Meteorology	WA HQ	Yes	Provide operational climate forecasts and crop monitoring
Airbus Defence and Space	Global company with WA presence	Yes	Provide designing, manufacturing and delivering aerospace products, services and solutions
Ajilio		Yes	
Alexander Symonds	No. SA and Vic based company	No	Leading surveying consultancy firm
Amazon Web Services	No	No	A digital catalogue with thousands of software listings from independent software vendors
Amstar (Syngenta)	Global company with WA presence	Yes	Agriculture company helping to improve global food security by enabling millions of farmers to make better use of available resources
Anita		Yes	
Astron	Yes	Yes	Environmental consulting firm
Atomic Sky	WA Company	Yes	Promoting collaboration in Space and other industries
Aurecon	Global company with WA presence	Yes	Engineering and infrastructure advisory firm
B&P Surveys	No. Qld and NSW based company	No	Surveying, planning and urban design
Balance Utilities Solutions	Yes	Yes	Space Installation, defence and big data
BHP	Global company, WA HQ	Yes	Mining, oil and gas
Black tree Inc.	American company		Niche UHF applications
Brazier Motte	No. Qld based company		Surveying and town planning firm

Company	Description	WA presence	Business description
Business Aspect	National company with WA presence	Yes	Technology and business advisory firm
C.R.Kennedy	Global company with WA presence	Yes	Survey, construction and photo imaging
Case IH	International company with WA presence	Yes	Market leading agricultural solutions and services, advance farming systems
CIRA	Yes	Yes	Curtin's link with the International Centre for Radio Astronomy Research
CISCO	Global company with WA presence	Yes	Multinational technology conglomerate
DDN	Global company with Qld presence		Provider of large storage systems for unstructured data and big data environments
Eco Logical	National company with WA presence	Yes	Environmental consulting firm
Eomap	Global company with no presence in WA		Earth observation and environmental consulting firm
EOS Space Systems	National company with WA presence	Yes	Technology company operating in the aerospace and defence markets
eSpatial	Global company with no presence in WA		Spatial software company
Farm & Co		Yes	
Facey Group	Perth presence	Yes	Agriculture livestock management, fertiliser and harvesting technologies
Fastwave	Yes	Yes	Focus on integrating satellite telemetry systems with sensors, process control equipment and terrestrial communication systems to provide global, real-time asset visibility.
Fortescue Metals	WA HQ	Yes	Mining
Fugro	Global company with WA presence	Yes	Global offshore and onshore geotechnical and survey services
Fujitsu		Yes	
Future Engineers and Communications	WA HQ	Yes	Organisation that specialises in design, supply and installation of Powerline Infrastructure, Lattice Towers, Steel Monopoles, Guyed Masts and custom designed structures
Gaia Resources	WA and Qld offices	Yes	Environmental Technology Consultants
Geospatial Intelligence	Working with Landgate	Yes	GIS
Reimage	Qld based firm with WA presence	Yes	Satellite Imagery and Geospatial Solutions
Go	Yes	Yes	Electrical contractor for industrial and infrastructure projects.
GHD	Australian company with WA presence	Yes	Multidisciplinary engineering firm
GlobalPOS	Reseller for Septentrio GNSS receivers	Yes	

Company	Description	WA presence	Business description
GPSat	Vic based company	unsure on what this is	
IBM	Global company with WA presence	Yes	Business solutions, security solutions and storage solutions
Inmarsat solutions BV	Global company with WA presence	Yes	British satellite telecommunications company, offering global mobile services
Insight GIS	Tasmanian based company	No, may have serviced WA	IT company that specialises in geographic information systems (GIS) and location intelligence
Intel	Global company	Yes	Multinational corporation and technology company
Innovate Australia	WA Company	Yes	Collaboration across a range of industries including space
Innovation Central	Collaboration between CISCO, Woodside and Data 61	Yes	Collaboration and communication
I Paddock	Yes	Yes	Provides smart farming Apps and farm equipment
Jacobs	Global company with WA presence	Yes	Multidisciplinary engineering firm
Jet Cut Tooling Solutions		Yes	unsure on what this is
John Deere	National company with WA presence	Yes	Agriculture equipment supply company
Caelus	Global firm with Qld presence	Yes	Focus test and measurement instruments, cell-site filters, combiners and tower mounted amplifiers
Kakadu Software	National company with NSW HQ	Yes	
L3 Oceania	Global company with WA presence	Yes	Predominantly electronics company servicing the defence market
Land Equity International	No. Located in NSW	No, may have serviced WA	Specialise in land administration, land policy and land tenure.
Leica Geosystems	Hard to tell, global company with HQ in EU	Yes	Specialise in capture, analyse and present spatial information
Lockheed Martin	Global company with WA presence	No, hard to tell	American global aerospace, defence, security and advanced technologies company
Mercury Project Solutions	National company with WA presence	Yes	Collective of Independent Spatial Information Consultants
Miller Nitro		Sell through WA dealership	Agriculture equipment supply company
New Holland		Sell through WA dealership	agriculture equipment supply company
NGIS Australia	National company with WA presence	Yes	Geographic information system applications and software company
Numerica	Global company with WA presence	Yes	
NVIDIA		Hard to tell, may service WA	Multipurpose technology company

Company	Description	WA presence	Business description
Omni link	No. National firm	Yes	Provide property and location data management solutions
Photomapping Services	No. Vic based firm	No	Involved in all aspects of acquisition, production, presentation and the management of geospatial data and can provide services to any client, large or small. Our range of cutting edge remote sensing technologies, modern twin-engine aircraft and dedicated flight crews can respond to aerial LiDAR and Digital Photography requests throughout Australia, Asia and the Pacific region.
Picosat Systems	Yes	Yes	Provider of small satellite solutions. Its pico-satellite platform technology takes advantage of the small satellite revolution.
Pointerra	Perth based company growing globally	Yes	3D models and data analytics
Position Partners	National company with WA presence	Yes	Provider of positioning and machine control solutions for surveying, civil works and building activities.
PSMA Australia	No. ACT based firm	No, may have serviced WA	Source geospatial information from trusted sources. We curate the data into authoritative products that are being widely used by business and government to make everyday decisions.
Raytheon		Yes	Provides state-of-the-art electronics, mission systems integration and other capabilities in the areas of sensing; effects; and command, control, communications and intelligence systems; as well as a broad range of mission support services
Rio Tinto		Yes	Mining
Romtek		Yes	Leader in the design, manufacture and deployment of IoT solutions that support essential services and processes, providing newer and better methods for monitoring, tracking and control.
SGL Systems			
Silion Graphics Industry (SGI)		Yes	Computing manufacturer, producing computer hardware and software company.
Sky and Space Global	Yes	Yes	First company to plan, build and operate a telecommunication commercial network over Nano-Satellites.
Spatial Vision	No. Vic based firm servicing NZ	No, may have serviced WA	Specialist in spatial information and technologies.
Spiriti River		Yes	

Company	Description	WA presence	Business description
SSC Space Australia	Subsidiary of Swedish Space Corporation	Yes	As part of its commitment to the provision of support within this region, SSC established a subsidiary, SSC Space in Australia in 2009 and has committed investment funds to establish ground station facilities at Mingenew for third party support and hosting.
Sundown Pastoral	No, NSW based farm	No	Production of high quality beef cattle as well as high quality irrigated cotton production, wheat, sorghum, pulse crops, Lucerne and other forage crops.
Superair	National company with WA presence	Yes	Arial fertiliser company
Systemmic		Yes	
Takor Group		Yes	Use modern equipment used to visualise, measure and analyse the earth in terms of location. This usually involves GPS (global positioning systems) and GIS (geographical information systems).
Thales	Global company with WA presence	Yes	Design, operate and deliver satellite-based systems that help them position and connect anyone or anything, everywhere, help observe our planet, help optimize the use of our planet's – and our solar system's – resources.
Think Bottom Up	WA Based	Yes	Software Developers
ThinkSpatial	No. Vic base firm	Yes	Spatial information company dealing in mapping, surveying, Arial systems, software
Thoughtworks		Yes	Software Developers
Top Con		Yes	Geopositioning, construction and precision agriculture
Trimble	Global company with WA presence	Yes	Global Positioning System receivers, laser rangefinders, unmanned aerial vehicles, inertial navigation systems and a variety of software processing tools.
Twynam Agricultural Group	No. NSW based farm	No	Agriculture group
Umwelt		Yes	Environmental consulting company
Unify		Yes, hard to tell	Software developers
Vantage WA		Yes	Agricultural Solutions and Precision Ag products
VPAC	No. Vic based Universities	No, may have serviced WA	Engineering consultants
Western Digital (HGST)		Yes	Software Developers
Whelans		Yes	Town planning, urban design, surveying and spatial solutions business
Wesfarmers	Diversified business with an agricultural component	Yes	Precision farming technology
Woodside		Yes	Global Oil and gas firm. Innovating in remote sensing, remote operations and robotics

Company	Description	WA presence	Business description
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SOURCE: ACIL ALLEN CONSULTING

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