Parliamentary Committees



Inquiry into job creation opportunities in Queensland arising from the establishment of an Australian space industry

Report No. 23, 56th Parliament
State Development, Natural Resources and Agricultural Industry Development Committee

February 2019

State Development, Natural Resources and Agricultural Industry Development Committee

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Acknowledgements

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Abbreviations

ACT	Australian Capital Territory
ADF	Australian Defence Force
the Agency	Australian Space Agency
ASC	Arnhem Space Centre
CDSCC	Canberra Deep Space Communication Complex
CSIRO	the Commonwealth Scientific and Industrial Research Organisation
DMTC	Defence Materials Technology Centre
DNRME	Department of Natural Resources, Mines and Energy
DSN	Deep Space Network
DSDMIP/the department	Department of State Development, Manufacturing, Infrastructure and Planning
EO	Earth Observation
EOA	Earth Observation Australia
ERG	Expert Reference Group
ELA	Equatorial Launch Australia
GEO	Geostationary Earth Orbit
GIS	Geographic Information Systems
GPS	Global Positioning System
IALPG	International Aerospace Law & Policy Group
IP	Intellectual Property
LSA	*Legislative Standards Act 1992*
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
OECD	Organisation for Economic Co-operation and Development
PFI	Products for Industry
PNT	Positioning, Navigation and Timing

R and D/R & D	Research and Development
the Review	Review of Australia's Space Industry Capability – Report from the Expert Reference Group for the Review
SMEs	Small to Medium Enterprises
STEM	Science, Technology, Engineering and Mathematics
SIAA	Space Industry Association of Australia
SSA	Space Situational Awareness
QCAT	Queensland Centre for Advanced Technologies
QUT	Queensland University of Technology
UQ	University of Queensland

Chair's foreword

> *Space technologies and services impact on the lives of Australians every day. They touch virtually every sector of the Australian economy. Australian farmers use space capabilities to monitor the health of their crops, marine pilots guide cruise liners, emergency workers track the progress of bushfires, and scientists study the effects and impact of droughts. Space is also inspiring young Australians. It is catalysing today's students to take an interest in STEM subjects, and move on to become our next generation of scientists and engineers.*[1]

This report presents a summary of the State Development, Natural Resources and Agricultural Industry Development Committee's inquiry into job creation opportunities in Queensland arising from the establishment of an Australian space industry. The committee's task was to consider the supply chain needed to develop and support the space industry and identify Queensland's areas of competitive advantage.

Queensland is already part of the space industry as a consumer, and it became increasingly clear throughout the inquiry that Queensland has numerous advantages to offer the space industry and is remarkably well-placed to fill many niches as a supplier within the space supply chain. Queensland's businesses and workforce already have the capacity to be part of the space industry. With government support there is the opportunity to build on these businesses to create new Queensland jobs, and to extend these opportunities to regional Queensland.

During the inquiry the committee witnessed the Black Sky Aerospace sub-orbital rocket launch, near Goondiwindi, which was the first sub-orbital launch in Australia. The committee also visited Gilmour Space Technologies in Pimpama and saw firsthand its ground control station, mobile rocket launcher and One Vision Rocket. The committee held a hearing at the University of Queensland and met with key researchers in the launch and earth observation sector, and visited the Australian Centre for Robotic Vision at the Queensland University of Technology. The committee also travelled to the Australian Capital Territory and met with government, academics, space scientists and other stakeholders.

On behalf of the committee, I thank those individuals and organisations who made themselves available to meet with the committee and those who made written submissions on the inquiry. I also extend the committee's thanks to officers of the Department of State Development, Manufacturing, Infrastructure and Planning, in particular the members of the Defence Industries Queensland team.

I would also like to thank members of this committee for their commitment and bi-partisan approach to this inquiry. Thank you also to our Parliamentary Service staff.

I commend this report to the House.

Chris Whiting MP

Chair

[1] Australian Space Agency, submission 21, p 1.

Recommendations

1 Introduction

1.1 Role of the committee

The State Development, Natural Resources and Agricultural Industry Development Committee (committee) is a portfolio committee of the Legislative Assembly which commenced on 15 February 2018 under the *Parliament of Queensland Act 2001* and the Standing Rules and Orders of the Legislative Assembly.[2]

The committee's areas of portfolio responsibility are:

- State Development, Manufacturing, Infrastructure and Planning
- Natural Resources, Mines and Energy, and
- Agricultural Industry Development and Fisheries.

Section 92(2) of the *Parliament of Queensland Act 2001* provides that a portfolio committee is to deal with an issue referred to it by the Assembly, whether or not the issue is within its portfolio area. Section 92(3) states that a committee may deal with such a matter by considering the matter; and reporting on the matter, and making recommendations about it, to the Assembly.

1.2 Referral and terms of reference

On 6 September 2018, the Legislative Assembly, referred an inquiry to the State Development, Natural Resources and Agricultural Industry Development Committee to examine the opportunities to create jobs across Queensland and promote existing supply chain capability from the establishment of an Australian space industry.

In undertaking this inquiry, the committee considered the following terms of reference:

a. The Australian Government's establishment of an Australian Space Agency on 1 July 2018;

b. The space supply chain, which has been broadly categorised as, Space systems (including communication satellites), Ground systems, Applications and ancillary services, and End use (e.g. improved telecommunications, mapping and emergency management);

c. The review of space supply chain capability released by the Australian Government prior to the Agency being announced;

d. Queensland's areas of competitive advantage in relation to identified capability which, at a high level, have been identified as communications, earth observations, position, navigation and timing; and

e. Areas of regional Queensland where supply chain capability exists, particularly in areas of competitive advantage.

1.3 Inquiry process

On 18 September 2018, the committee invited stakeholders and subscribers to make written submissions on the inquiry. The committee received 26 submissions on the inquiry (Appendix A provides a list of submitters). The committee received written advice on 24 October 2018 from the Department of State Development, Manufacturing, Infrastructure and Planning (the department/DSDMIP) in response to matters raised in submissions.

The committee received a public briefing in regard to the terms of reference of the inquiry from DSDMIP and the Department of Natural Resources, Mines and Energy on 15 October 2018. The committee also received a public briefing from the Department of Education and the Department of

[2] *Parliament of Queensland Act 2001*, section 88 and Standing Order 194.

Employment, Small Business and Training on 12 November 2018 (see Appendix B for a list of officials at the briefings).

The committee held the following public hearings for the inquiry:

- 19 October 2018 (University of Queensland, St Lucia Campus)
- 16 November 2018 (Parliament House, Brisbane)
- 1 February 2019 at (Parliament House, Brisbane)

Appendix C contains a list of witnesses for each public hearing.

During the inquiry the committee conducted three site visits:

- 21 November 2018 – the committee witnessed the Black Sky Aerospace sub-orbital rocket launch, near Goondiwindi, which was the first sub-orbital launch in Australia.
- 16 November 2018 – the committee visited the Australian Centre for Robotic Vision, located at Queensland University of Technology (QUT), Gardens Point Campus.
- 1 February 2019 - the committee visited Gilmour Space Technologies in Pimpama and viewed the company's ground control station, mobile rocket launcher and One Vision Rocket.

The committee also met with the Australian Capital Territory (ACT) government, academics, scientists and other stakeholders in Canberra on 19 and 20 November 2018.

As part of its inquiry process, the committee released two information papers:

- Information Paper 1: What is the space industry? (November 2018)
- Information Paper 2: What does the space industry require? (February 2019)

The submissions, correspondence from the department, transcripts of the briefings and hearings, and information papers are available on the committee's webpage.[3]

Committee members with researchers and astronomers at ANU Research School of Astronomy and Astrophysics, Canberra, ACT on 19 November 2018.

[3] The committee's webpage for this inquiry can be accessed at https://www.parliament.qld.gov.au/work-of-committees/committees/SDNRAIDC/inquiries/current-inquiries/10SPACE

2 The Australian space sector

Australia's journey into space has been mercurial to say the least and it could be argued that we have slipped from third to second last. Australia was the third country in the world, after the then USSR and the United States, to launch our own designed and built satellite into orbit from our own territory. In 1967, two years before American astronauts walked on the moon, Australia became just the third member of the exclusive space club. However, our membership lapsed to the point at which Australia was the second last developed country to establish a dedicated space organisation—the Australian Space Agency, which commenced operations in July [2018].[4]

2.1 Review of Australia's space industry capability

On 13 July 2017, the Australian Government 'announced a review of Australia's space industry capability (the Review) to enable Australia to capitalise on the increasing opportunities within the global space industry sector.'[5] The Review was argued to be 'timely, given the current pace of change in the international space sector and advances in technologies that provide an environment that encourages commercial investment in space activities'.[6]

An Expert Reference Group (ERG), chaired by the former CSIRO Chief Executive Dr Megan Clark AC, conducted the Review. The Review specifically address the following matters:

- identifying Australia's current industry capability and areas of comparative advantage for Australia to develop
- technologies and practices that promote innovation in both the downstream (users of space technologies) and upstream (providers of space technologies) elements of space activities, particularly in areas of niche capability and competitive advantage
- Australia's level of regional engagement and international collaboration, including identifying critical future and existing partnerships
- identifying capability gaps to support the global competitiveness of Australian firms in the civil space sector
- strategies to promote Australian firms engaged in the civil space sector, both domestically and internationally
- risks and opportunities, including ongoing access to space data and associated infrastructure essential to our national interests
- alignment with other sectors and Australian Government priorities, including Defence and cyber security, and meeting Australia's international obligations, and
- the most effective institutional arrangements to support the strategic direction of Australia's space industry.[7]

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4 Ms Denise Johnston, DSDMIP, public hearing transcript, Brisbane, 15 October 2018, p 1.

5 Australian Government, *Review of Australia's Space Industry Capability: Report from the Expert Reference Group for the Review*, March 2018, p 9.

6 Senator the Hon Arthur Sinodinos, AO, Minister for the Department of Industry, Innovation and Science, Media Release, *Expert review of Australia's space industry capabilities to participate in global market*, 13 July 2017.

7 Australian Government, *Review of Australia's Space Industry Capability: Report from the Expert Reference Group for the Review*, March 2018, p 9.

The Review's core findings were that:

- Australia's space industry already employs about 10,000 people and was worth AU$3.9 billion in the 2015–16 financial year
- Australia has a vibrant community of active small and medium-sized enterprises and world-leading capability in research
- stakeholders expressed a strong need for an Australian space agency.[8]

2.2 Establishment of the Australian Space Agency

On 14 May 2018, the Australian Government announced its response to the Review and committed to establishing an ongoing national space agency. The Australian Government envisioned that:

> *The Agency will be Australia's outward facing 'front door' to the world on civil space matters and will also be tasked with reaching out to create partnerships with other space agencies and nations for the purposes of cooperating and opening doors for Australian businesses to access international projects. The creation and nurturing of these international partnerships is a key objective for the Agency in its first years of operation. This will be supported through the International Space Investment initiative over three years, which will enable the Agency to partner with international space agencies. This investment will provide Australian businesses opportunities to be involved in established international space programs, with direct benefits to Australia.*[9]

The 2018-2019 Australian Government Budget provided $300 million for space-related measures to grow Australia's domestic space industry, including $41 million towards the establishment of the new Australian Space Agency (the Agency)[10] and $15 million to support international engagement.[11]

Commencing operations on 1 July 2018, the Agency is a non-statutory, whole-of-government entity that was originally located in Canberra within the Australian Department of Industry, Innovation and Science. [12] On 12 December 2018 the Australian Government announced that the Agency would be located in Adelaide.[13]

Mr Murfett, Deputy Head of the Agency, informed the committee that the Agency's purpose is:

> *… to grow and transform a globally respected Australian space industry that lifts the broader economy and inspires and improves the lives of Australians underpinned by strong national-international engagement.*[14]

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8 Australian Government, Department of Industry, Innovation and Science, *Review of Australia's space industry capability*, https://www.industry.gov.au/data-and-publications/review-of-australias-space-industry-capability, accessed: 12 December 2018.

9 Australian Government, *Australian Government Response to the Review of Australia's Space Industry Capability*, May 2018, pp 2-3.

10 Space Industry Association of Australia, submission 8, p 2.

11 Australian Space Agency, Department of Industry, Innovation and Science, *Welcome to the Australian Space Agency*, September 2018, p 3.

12 Australian Space Agency, Department of Industry, Innovation and Science, *Australian Space Agency Charter*, October 2018, p 1.

13 Dr Megan Clark, *Australian Space Agency location and identity*, available at: https://www.industry.gov.au/news-media/australian-space-agency-news/australian-space-agency-location-and-identity-a-message-from-head-dr-megan-clark-ac, accessed 7 January 2019.

14 Mr Anthony Murfett, Australian Space Agency, public briefing transcript, Brisbane, 16 November 2018, p 2.

Under its broad mandate, the Agency has six primary responsibilities:

1. *Providing national policy and strategic advice on the civil space sector.*
2. *Coordinating Australia's domestic civil space sector activities.*
3. *Supporting the growth of Australia's space industry and the use of space across the broader economy.*
4. *Leading international civil space engagement.*
5. *Administering space activities legislation and delivering on our international obligations.*
6. *Inspiring the Australian community and the next generation of space entrepreneurs.* [15]

This mandate supports the national civil space priorities which include:

- communications technologies, services and ground stations
- Space Situational Awareness (SSA) and debris monitoring
- Positioning, Navigation and Timing (PNT) infrastructure
- Earth Observation (EO) services
- research and development
- remote asset management
- developing a strategy to position Australia as an international leader in specialised space capabilities.[16]

According to the Australian Space Agency, the three priority areas where Australia has existing space industry capability include:

1. Space services
2. Space tracking
3. Space exploration.[17]

Witnesses to this inquiry welcomed the establishment of the Agency. Mr Nikolic, Director of Black Sky Aerospace, told the committee:

> *…the Australian government's establishment of the Australian Space Agency has been a positive and much needed step towards the future of Australia's involvement in a rapidly growing ecosystem.*[18]

Similarly, Professor Phinn, Director of the Remote Sensing Research Centre and Joint Remote Sensing Research Program, University of Queensland (UQ), and the Director of Earth Observation Australia (EOA), said:

> *This is a positive and significant first step in enabling Australia to build space industry capability and generate jobs and economic growth. Specifically, it will enable national coordination and direct international engagement at government and whole of industry levels.*[19]

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15 Australian Space Agency, Department of Industry, Innovation and Science, *Australian Space Agency Charter*, October 2018, p 1.

16 Department of Industry, Innovation and Science, *Australian Space Agency*, available at: https://www.industry.gov.au/strategies-for-the-future/australian-space-agency, accessed 7 January 2019.

17 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

18 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 21.

19 Professor Stuart Phinn, submission 10, p 3.

Ms Melroy, Director of Space Technology and Policy, Nova Systems, stated that the Agency provides an opportunity for Australia to bring its unique capabilities to the global space community and emphasised that it must be a whole-of-Australia effort.

> *Although individual states each have strengths, there is key expertise that exists in all states and territories that must be leveraged if Australia is going to be able to earn its seat at the table of the international space community.*[20]

The Agency promotes a 'Team Australia' approach, where every level of government, industry and research works collaboratively with one another to develop Australia's space economy.[21]

2.3 The Queensland approach

The Queensland Government supports the Agency's 'Team Australia' approach to develop Australia's space economy.[22] Ms Johnston, Executive Director, Defence Industries Queensland, DSDMIP, told the committee:

> *Our view is that the federal government really need to lead Australia's position in the space industry. Queensland cannot act alone… Queensland is really positioning itself in terms of how do we build the industry and what do we think are the opportunities for industry in the state.* [23]

Ms Johnston emphasised that, in a global environment, Australia's states and territories cannot afford to compete with one other and must work together to compete with the rest of the world.[24] Some states and territories are already active in the space industry, such as South Australia, the Australian Capital Territory and the Northern Territory which have signed a memorandum of understanding and are investigating opportunities in the space industry.[25] The Queensland Government recognises the need to collaborate and coordinate with other states and territories as part of a national approach. Air Vice-Marshal (Retired) Neil Hart told the committee:

> *While Queensland has an important role to play, we need to do this as part of the larger Australian framework, which consists of all levels of government across the nation working together with industry, the research sector and Defence collaboratively in the national interest.*[26]

The space industry has been identified as a priority focus for the Queensland Government and consequently is supported by a cross-government working group consisting of representatives from DSDMIP and the departments of the Premier and Cabinet; Environment and Science; Innovation and Tourism Industry Development; and Natural Resources, Mines and Energy.[27] Leading the focus on space for Queensland is the government's Strategic Defence Adviser for Air and Chair of the Queensland Space Industry Reference Group, Air Vice-Marshal (Retired) Neil Hart. The Group is tasked with driving 'the Queensland Government's engagement with industry, research, government and Defence personnel on existing and emerging opportunities in Queensland to support and grow our space industry'.[28] Opportunities to support the growth of the state's aerospace industry are documented in Queensland Aerospace 10-Year Roadmap and Action Plan. [29]

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20 Ms Pam Melroy, submission 24, p 4.

21 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

22 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

23 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 5.

24 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

25 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

26 Air Vice-Marshal Neil Hart (Retired), public hearing transcript, St Lucia, 19 October 2018, p 44.

27 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 4.

28 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3.

29 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3.

3 Space

Space begins at the Kármán line, an altitude 100 kilometres above sea level and the point at which earth's atmosphere becomes too thin for aeronautical purposes.[30]

Historically, space exploration and the space industry have been the reserve of national governments. However, as a result of low cost technological innovation and an increased demand for space based and space derived services, this model is changing. The commercialisation of space is allowing increasing numbers of non-state participants to access and use space. Mr Murfett, Deputy Head of the Australian Space Agency noted:

> *…technology is smaller, technology is cheaper and the cost of launch is reducing, which means that with space activities what was once the realm of government only is now a place where commercial providers can make commercial realities through space, whether that be through very small satellites, the use of space data or provisioning commercial launch.*[31]

The private sector's involvement in and its commercialisation of space is referred to as Space 2.0.

> *The old approach of taxpayer-funded, government-run space programs (such as NASA in the US) is Space 1.0. The new approach, Space 2.0, emphasises commercial space enterprises as leaders and exploits new technologies that deliver low costs and high returns in good time.*[32]

While governments will still be required to play a role in the space industry, it is argued that this role will change from being the sole service provider to becoming that of industry facilitator and regulator.[33]

Significantly, as technology and space activities become commercialised, the space sector will become more adaptive and less constrained by geographic location.

> *With this kind of technology … you do not have to really be anywhere in Space 2.0. As long as you have a team of talented people and a decent industry base, you can operate it anywhere.*[34]

3.1 The space economy

> *By 2040, the global space economy is expected to have tripled in size to at least US$1.1 trillion, as demand for services escalates, and disruptive technologies such as reusable rockets and mass-produced satellites force costs down by several orders of magnitude.*[35]

Internationally the space industry is currently worth US$345 billion each year. The Australian space sector contributes just 0.8% to the global space economy,[36] and employs around 10,000 full time equivalents. In Australia, the space sector comprises around 388 companies, 56 education and research institutions and directly involves around 24 government agencies.[37]

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30 Australian Government, *Review of Australia's Space Industry Capability: Report from the Expert Reference Group for the Review*, 2018, p 11.

31 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 2.

32 Australia by the Australian Strategic Policy Institute, *Australia's Future in Space*, 2018, p 6.

33 Mr James Minchinton, submission 12, p 2.

34 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

35 Australian Government, *Review of Australia's Space Industry Capability, Report from the Expert Reference Group for the Review*, 2018, p 15.

36 Australian Space Agency, *Welcome to the Australian Space Agency*, available: https://www.industry.gov.au/data-and-publications/welcome-to-the-australian-space-agency

37 Acil Allen Consulting, *Australian Space Industry Capability, A Review, Report to Department of Industry, Innovation and Science*, 2017, p i.

The space economy is a broad economic sector built around the generation and consumption of data gathered by a new generation of satellites. It feeds directly into phones and mobile devices, providing entertainment and information, and is a sector driven by both business opportunity and military requirements. The space economy goes well beyond the space sector itself, to include the impacts of space-derived products, services and knowledge on the economy and society.

The Organisation for Economic Co-operation and Development (OECD) defines the space economy as:

> *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.*[38]

The Expert Reference Group which undertook the Review has estimated Australia's space market size in the 2015–2016 financial year at AU$3.94 billion.

> *This amount comprises Defence-related expenditure of AU$175 million; non-Defence Government expenditure in agencies such as the CSIRO, the Bureau of Meteorology, Geoscience Australia, and the Australian Communications and Media Authority (ACMA) of AU$126 million; university space-related research of AU$44 million; and a commercial segment of AU$3.598 billion… The ERG found that the main segments of Australia's commercial space industry in the 2015–2016 financial year were direct-to-home TV (49 per cent); satellite communications and broadband (23 per cent); ground station infrastructure and operations (8 per cent); and high-technology equipment manufacturing and services (5 per cent).*[39]

The increased commercialisation of space has seen significant private investment in the sector, and in particular, in satellites and launch capabilities. Mr Gilmour, CEO and founder of Gilmour Space Technologies, told the committee:

> *The upstream space industry has had more than $10 billion of venture capital investment in the last six years which is a huge number. Even in Australia it is over $50 million or $60 million in investment just in the last two years—all on upstream technologies, which is launch vehicles and satellites.*[40]

Additionally, Professor Stuart Phinn from UQ highlighted the significant growth in earth observation activities in the space sector.

> *If you look at the reports and market forecasts for space industry growth, the compound annual growth rate for the next couple of years is eight to 10 per cent. The share of that growth in terms of earth observation activities, at least on the Asia-Pacific side of it, is around 30 per cent potentially. That is quite a large potential market increase that we can take advantage of.*[41]

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38 OECD, *Handbook on measuring the space economy*, Paris: OECD, 2012; OECD, *Space economy at a glance*, Paris: OECD, 2014.

39 Australian Government, *Review of Australia's Space Industry Capability, Report from the Expert Reference Group for the Review*, 2018, p 18.

40 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

41 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 27.

The value of space activity to the Australian community was highlighted by Dr Williams, Executive Director, Digital, National Facilities and Collections, CSIRO:

> *For every dollar that you spend on a space activity you probably can get a return of $4 on the added value of the data if it is earth-observing data or geophysical GPS data. Then there is the spin-out to the community in general. It is a value chain of how the value flows back to a country.*[42]

3.2 The space supply chain

The development of a space industry is reliant on a multifaceted supply chain. Mr Minchinton informed the committee:

> *A space industry will require, inter alia, land on which to carry out activities (including land for launch facilities, communication facilities and other infrastructure), research initiatives, natural resources and raw materials, manufacturing capabilities and transportation networks, all of which will need to be supported by a range of secondary service and related industries. These will, in turn, need to be nurtured and encouraged (at least in the early stages of its life cycle) through government initiatives and appropriate legislative regimes.*[43]

Ms Johnston from the department summarised:

> *Broadly speaking, the space industry supply chain begins with the development and launch of the spacecraft and ends with the application of the data delivered by these spacecraft.*[44]

The United Kingdom Space Agency has extended the OECD definition of the space economy to define components of the space supply chain:

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.[45]

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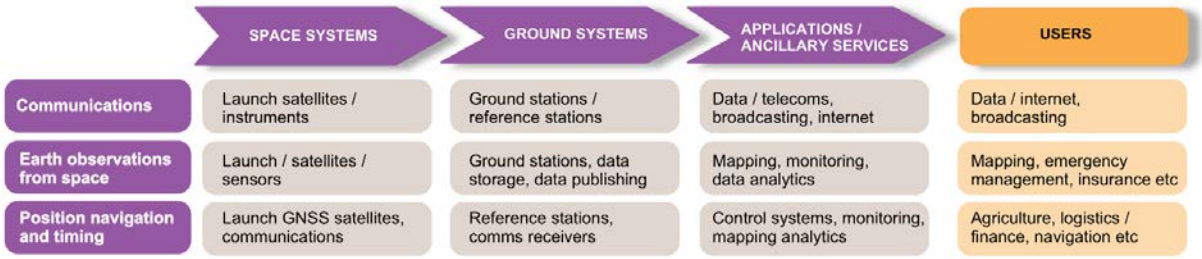
42 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 12.

43 Mr James Minchinton, submission 12, p 2.

44 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

45 Acil Allen Consulting, *Australian Space Industry Capability, A Review, Report to Department of Industry, Innovation and Science,* 2017, p B-1.



Space Industry Supply Chain[46]

Additionally, Mr Minchinton argued that the space supply chain could be viewed as a space technology supply chain:

> *The space supply chain can be viewed in the terms above, i.e. space systems, ground systems, applications and ancillary services, and end use. Another way to look at the space supply chain [is to] consider it as a space technology supply chain being a progression from the science, to the application, to engineering, to manufacturing, to production and end use. The space technology supply chain carries with it the potential for a space industry and for applications in other non-space, terrestrial activities.*[47]

CSIRO further developed the elements of the space economy supply chain to comprise both upstream and downstream activities.

> *The space value chain is broad, covering upstream activities which focus on ground systems, launch and operating objects in space, together with downstream activities that utilise space data and technologies across a range of applications. Downstream activities will continue to expand as the role of the space industry in the broader economy grows.*[48]

The Space Value Chain[49]

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46 Source: Acil Allen Consulting, *Australian Space Industry Capability, A Review, Report to Department of Industry, Innovation and Science*, 2017, p 1.

47 Mr James Minchinton, submission 12, p 3.

48 CSIRO, submission 5, p 1.

49 Source: CSIRO, *Space, A Roadmap for unlocking future growth opportunities for Australia*, 2018, p 4.

Due to Australia's late arrival into the space industry the Defence Materials Technology Centre (DMTC) highlighted that the space supply chain in Australia was not developed and lacked a well-established and networked end-to-end supply chain such as the partnerships between the research sector, Australian space start-ups and SMEs, and multinational primes.[50] The establishment of the Australian Space Agency at a national level, will significantly contribute to developing a networked supply chain in Australia.

Mr Blake, Space Law and Strategy Consultant, International Aerospace Law & Policy Group (IALPG) told the committee that Queensland's and Australia's entry into the space supply chain should not be a replication of internationally established components:

> *We submit that there are two related key words that could form the core themes of the Queensland approach to its part in the global space industry and would provide the best possible direction and guidance to promote jobs and industry in Queensland. Those words are 'supplementary' and 'complementary' …*
>
> *Firstly, Australia does not need to replicate the space infrastructure of our friends, allies and partners around the world; we can supplement the existing infrastructure. Secondly, the surest path to global success for Australia is by synergistic cooperation within the entire Australian space community. That is, the activities of all entities in the Australian space community should complement one another wherever possible.*[51]

Dr Dowse AO, Air Vice-Marshal (Retired), Director of Defence Research and Engagement at Edith Cowan University, similarity highlighted that the space supply chain should be understood as a whole capability, or an integrated system of systems which need to work together:

> *It is entirely likely that Queensland firms will be part of an overall supply chain and deliver only part of the integrated system; however, if these parts do not all work together or are not delivered in a timely manner, the impact on the program, the revenue and the whole industry would be substantial.*[52]

Ms Johnston, DSDMIP, told the committee:

> *Australia does not have the capability, time, or budget required to develop our own end-to-end space ecosystem.*
>
> *The department supports this objective, understanding that our role is to develop and leverage existing capability into niche areas of the global space supply chain.*[53]

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50 Defence Materials Technology Centre, submission 4, p 3.

51 Mr Duncan Blake, Space Law and Strategy Consultant, International Aerospace Law & Policy Group (IALPG), public hearing transcript, Brisbane, 16 November 2018, p 38.

52 Dr Andrew Dowse AO, Air Vice-Marshal (Retired), public hearing transcript, Brisbane, 1 February 2019, p 12.

53 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

4 Space systems

Space systems can broadly be defined as design and/or manufacture of space equipment, operating components and systems based in space, for example, the design or manufacture of launch vehicles, satellites and spacecraft, control centres, the supply of relevant materials or components, scientific and engineering support.[54] Space systems also include launch sites, launch activities and services related to the launch of space systems.

4.1 Launch services

Space launch for Australia started with the launch of the Weapons Research Establishment Satellite (WRESAT) in Woomera in November 1967. Australian governments in the 1980s unsuccessfully considered satellite launch opportunities with sites in Queensland on Cape York and in the Northern Territory at Darwin, Gunn Point, Point Stuart and Nhulunbuy. Commercial organisations also investigated establishing spaceports at Christmas Island, in South Australia at Woomera, Queensland at Rockhampton, and Western Australia at Derby.[55]

The 2018 establishment of the Australian Space Agency[56] has reignited interest in developing a national space industry and the debate in regard to Australia's capability to offer launch services. Mr Nikolic, Black Sky Aerospace, argued:

> *For the industry to thrive, though, we must look at all aspects as if it were a puzzle, knowing that one missing piece could be crucial to overall success. This includes launch services, covering launch sites and launch vehicles.*[57]

Although Australia has been a significant user of launch services, having essentially no orbital or sub-orbital launch capability of its own, it is the area in which Australia has the least space capability.[58]

Australia Space Launch submitted that launch facilities directly impact on the growth of the sector:

> *… the experience of both growth, decline and now new growth in the US-based Space Industry is directly attributed to operational and active space launch facilities.*[59]

4.2 Launch facilities

During the inquiry the committee was repeatedly told of the need for Australian launch facilities in order to develop the space supply chain. In its submission, Products for Industry (PFI) argued:

> *The first stage in space industry supply chain is the provision of a space launch facility. This step has been overlooked in industry discussion and is an oversight with far reaching consequences…The space systems area of supply chain all include a launch component which we currently have to access internationally. The cost of transporting space technologies overseas for testing and launch is prohibitive.*[60]

CSIRO also identified the need for local launch facilities in the southern hemisphere to support Australia's developing space industry:

> *… without access to convenient commercial launch facilities, Australia's space industry needs to look offshore for launch capability. With only 12 countries housing orbital launch sites,*

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54 London Economics, *Size and Health of the UK Space Industry 2016 – Summary report*, 2016.

55 Equatorial Launch Australia, submission 19, p 1.

56 See section 2.2 in regard to the establishment of the Australian Space Agency.

57 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 21.

58 Products for Industry, submission 7, p 1

59 Australia Space Launch Pty Ltd, submission 15, p 1.

60 Products for Industry, submission 7, p 1.

> *Australia's southern hemisphere geography, wide range of usable site latitudes and low population density make it well suited for launch facilities that are capable of attaining most orbit inclinations.*[61]

The committee was also told that in the highly developed and competitive international market, Australia is unable to compete with large scale and well-established launch facilities:

> *We should not compare ourselves to NASA, which has been around for 60 years and has had access to over half a trillion US dollars. Large operations such as SpaceX and the United Launch Alliance have also been around for over a decade and have had the ability to piggyback off existing infrastructure and billions of dollars in cash and resources.*[62]

Yet the committee heard that Australia is well-placed to develop its own niche launch services:

> *… these bigger launch companies … have a niche market for massive satellites going to geostationary… When there is already a set-up to do those larger launches, someone who is paying hundreds of millions of dollars to launch does not want to sit around for a maybe to do that. They have a provider for that already. Our focus should be in that smaller market to allow rapid turnaround. Plus it is much easier for the infrastructure to be put in place.*[63]

While the large satellite launch market is well supplied, there is an unmet demand for launch capacity for small or nanosatellites[64] and the committee was told that this offers significant economic opportunities for Australia.[65]

> *The market value of launching satellites up to 50 kg is $2.5 billion dollars globally. Australia should seek to claim a share of that market. A space launch facility is an essential part of the space industry supply chain, linking industries in the upstream sectors (including manufacturing and technology industries) with the rapidly growing downstream industries (especially the satellite operators and data users).*[66]

The committee was advised that Australia currently has two commercial companies developing launch sites. 'Equatorial Launch Australia' which is developing the Arnhem Space Centre in the Northern Territory[67] and 'Southern Launch' in South Australia, which is developing capabilities for launch over the Great Australian Bight.[68] Both companies are developing Low Earth Orbit (LEO) launch capabilities for nanosatellites.

Equatorial Launch Australia is developing launch facilities that will focus on equatorial low earth orbit launches. Equatorial obits travel around the equator in the equatorial zone between +/- 15 degrees. Satellites launched close to the equator benefit from the 'sling shot effect' caused by Earth's rapid rotation at the equator, which gives a boost of 1650 kilometre/hour toward the east. This reduces the fuel load enabling heavier satellites to be launched.[69]

In contrast, Southern Launch is developing a space launch complex in South Australia to provide polar launch services over the Great Australian Bight. Polar orbits pass over the Earth's Polar Regions from

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61 CSIRO, *Space, A Roadmap for unlocking future growth opportunities for Australia*, 2018, p 20.

62 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 21.

63 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 24.

64 See section 3.3 for descriptions on types of satellites.

65 Australian Government, *Review of Australia's Space Industry Capability, Report from the Expert Reference Group for the Review*, 2018, p 52.

66 Products for Industry, submission 7, p 2.

67 Equatorial Launch Australia, submission 19, p 2.

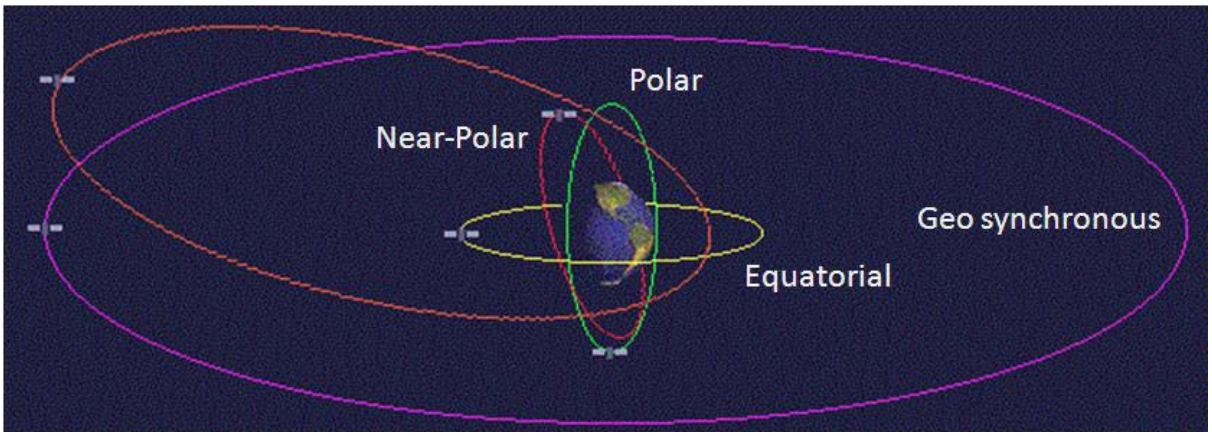
68 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 21.

69 European Space Agency, Liftoff from South America, available at: https://www.esa.int/esaKIDSen/SEMRCIXJD1E_Technology_0.html, accessed 5 December 2018.

north to south +/- 20 to 30 degrees of the poles. These orbits mainly take place at low altitudes of between 200 to 1000 kilometres. Satellites in polar orbit, at an altitude of 800 kilometres, travel at a speed of approximately 7.5 kilometres per second and take approximately 90 minutes to circle the Earth. Satellites in polar orbit move in the north-south direction while the Earth is moving perpendicular to the satellite, this enables polar satellites to scan the entire surface of the Earth several times a day.[70]

Satellite orbits are also defined in terms of their position to the Earth. Professor Phinn from UQ outlined:

> *… there are two sorts of orbits of satellites. Low-earth-orbit satellites are typically polar orbiting—that is, they are going around the earth closer to the equator. Those are all 400 to 700 kilometres above the earth's surface. Geostationary satellites are 30,000 to 36,000 kilometres away, so as the earth moves around those satellites stay in the same position. That is why they are used for communications.*[71]



Types of satellite orbits[72]

The committee heard that there are three general categories of satellites: Large geostationary satellites, small nanosatellites and between the two, mid-range satellites.

4.2.1.1 Geostationary Satellites

- positioned in geostationary (one location) orbits from 600 to 36,000 kilometres above the earth
- high levels of technology
- weigh several tonnes, and referred to as 'big birds'
- requires large launch vehicles
- expensive to build
- can take five to 10 years to build
- approximately 15 to 20 year lifespan[73]

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70 European Space Agency, Satellite Animal Tracking, available at https://www.esa.int/Our_Activities/Space_Transportation/Types_of_orbits; accessed 5 December 2018.

71 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 34.

72 Source: Galactic Canada, Satellites, available at: http://www.satellites.spacesim.org, accessed 5 December 2018.

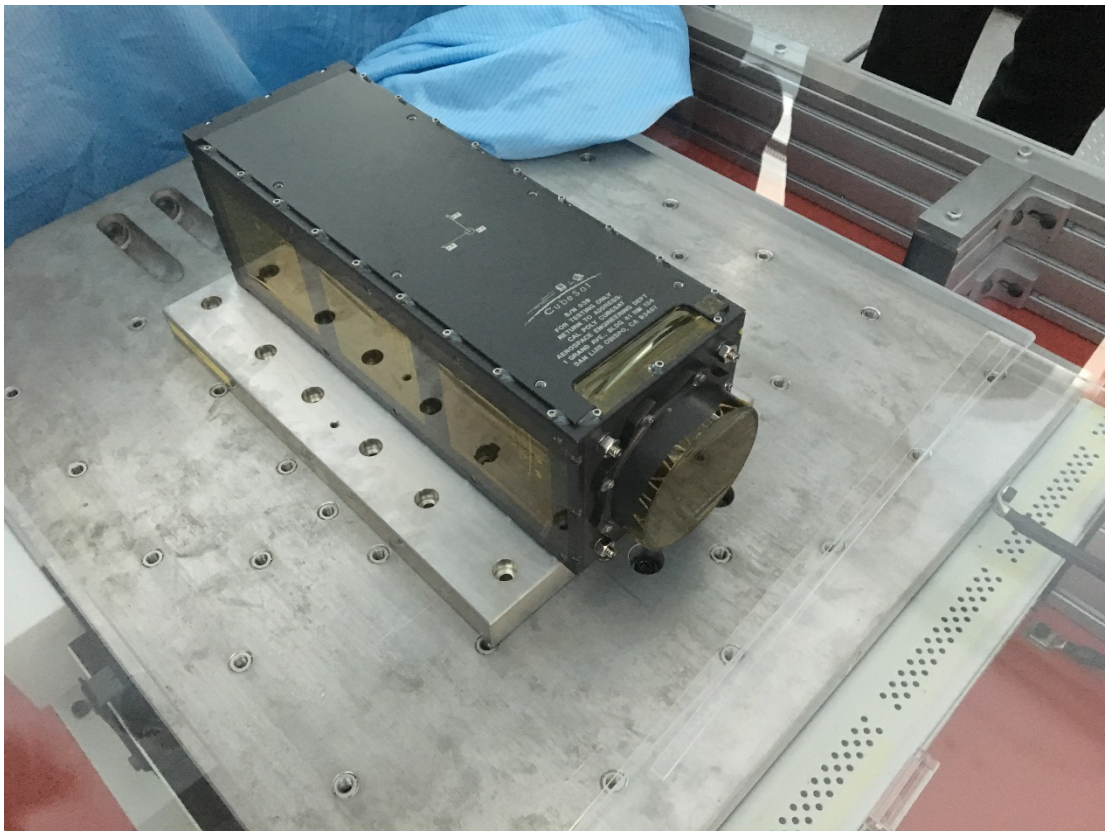
73 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, pp 9- 10; Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 30; Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 30.

4.2.1.2 Mid-range satellites

- weigh approximately 300 kilograms
- can carry bigger sensors, cameras and more communication channels
- sit in a higher orbit
- less costly to manufacture than geostationary satellites
- require smaller launch vehicles[74]

4.2.1.3 CubeSats/Nanosatellites

- 10 centimetres by 10 centimetres by 10 centimetres
- can be built to a stack of six units
- weigh approximately 5 kilograms each cube
- small, inexpensive and readily useable
- can carry small communication technologies and small cameras
- large numbers (100) of nanosatellites launch together to create constellations which also mitigates against failure of single satellites
- launch into low earth orbit
- can piggy-back on launch vehicles
- can photograph the whole earth in a day
- in orbit for approximately five to seven years
- slowly falls out of orbit and burns up.[75]



CubeSat at the Canberra Deep Space Communication Complex, 20 November 2018.

[74] Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, pp 9- 10.

[75] Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, pp 9- 10.

During the inquiry the committee was informed that given the different types of satellites and different requirements for launch into specific orbits, not all launch sites fulfil the same functions.[76] Therefore, it is necessary to have a variety of launch facilities, or a flexible launch site, to cater for different sections of the industry.[77]

4.3 Launch vehicles

The development of the launch vehicle industry is in its infancy in Australia. Globally, the number of commercial entities building launch vehicles is small. Mr Gilmour, Gilmour Space Technologies, told the committee:

> *There are probably 20 or 30 companies around the world that are having a good go at developing launch vehicles, but the process takes a long time. It takes five, six or seven years to do and the realisation in the market has only been in the last two or three years that this is a good business to go after. That is why there has been a bit of a technology lag. It is hard to build a rocket—very, very hard.*[78]

Similarly, Dr Sandy Tirtey, Launch Director and Director of Business Development (Australia), Rocket Lab commented on the difficulty in developing launch vehicles:

> *Developing an orbital vehicle is probably one of the hardest engineering tasks that you can think of, because it covers absolutely every single aspect of engineering.* [79]

Over the last 20 or 30 years, the launch vehicle market has focused on the manufacture of vehicles to put 10,000 to 20,000 kilogram satellites into orbit. However, under Space 2.0 there is a shift in activity from large to small satellite launches. Mr Gilmour explained:

> *If you look at SpaceX, Blue Origin, Arianespace, Northrop Grumman and NASA with the SLS, they are all building these vehicles that can take 40, 50 or 100 tonnes to orbit. I think everybody thinks everybody is going to the moon really soon and hoping to get a lot of business. However, what has not been developed until just recently—Rocket Lab are first—is the small-launch vehicle market. You have seen this trend in satellites where they get smaller and smaller, but the rocket industry was slow to catch that trend. This is why I am saying there is a bottleneck, because all these satellite companies are busy making all these satellites and the small-launch market is not ready yet. We are still two years away from being able to launch. There is probably only another two companies that will be able to launch in the next 12 to 18 months. By the time it gets to 10 launch vehicles, it could be five years away, so there is going to be a big bottleneck.*[80]

Currently, small satellites use ridesharing where there is spare capacity in a launch vehicle as a way to launch into orbit. While this method has benefits in terms of cost sharing, launch of secondary payloads are dependent upon the primary customer's timetable and capacity to accommodate all components of the secondary payload.[81] Professor Smart, UQ, explained to the committee:

> *At present, almost all small satellites are launched on a rideshare with a larger service. In those instances, both the orbit and the date of launch are set by the customer—the main customer. The small satellite operator has no control whatsoever. This situation going forward is just not satisfactory for commercial means, for defence or even for scientific activities. Therefore, there*

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76 Mr Lau Saili, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 7.

77 Professor Michael Smart, submission 13, p 3.

78 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 17.

79 Dr Sandy Tirtey, Rocket Lab, public hearing transcript, Brisbane, 1 February 2019, p 24.

80 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 17.

81 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 11.

is a significant commercial opportunity for the development of what are known in the industry as dedicated launchers. That means launchers that are designed to launch something as small as 100 kilograms into a specific orbit, so each one of those 648 small satellites can go into a slightly different orbit.[82]

4.4 Demand for launch facilities

The committee was told that there is a significant emerging market around nanosatellites and therefore a strong business case to develop launch facilities for this segment. Professor Smart, Chair of Hypersonic Propulsion, School of Mechanical and Mining Engineering, UQ, stated:

The market for small satellites is growing. A 2017 survey by Euroconsult predicts 6200 small satellites to be launched in the 2017-26 period with an estimated launch cost of US$13.6 Billion. This growth is driven by the needs of customers like Oneweb, which has FAA approval to operate a constellation of 648 small satellites to supply high speed broadband anywhere on the globe.[83]

Similarly, Mr Gilmour, Gilmour Space Technologies, highlighted the expected demand for small/mid-range satellite launch services in the near future:

There is a bottleneck in the market. We look at how many companies are out there that intend to launch satellites that have good levels of funding... We track who actually has tens of millions or hundreds of millions or billions of dollars and is actively manufacturing small satellites. Just that number is 5,000 or 6,000 satellites and they are in the 200- to 400-kilogram range… they have an average life span of five to seven years. If you think about it, on average, there is going to be a thousand of these satellites that have to go up each year and they have to go up on an independent launch vehicle because they are all in independent orbits. The frequency of the launch is going to become massive and the market is not ready for that.[84]

The Review identified a significant growth in the nanosatellite sector over the past 20 years. Mr Murfett, Australian Space Agency, informed the committee:

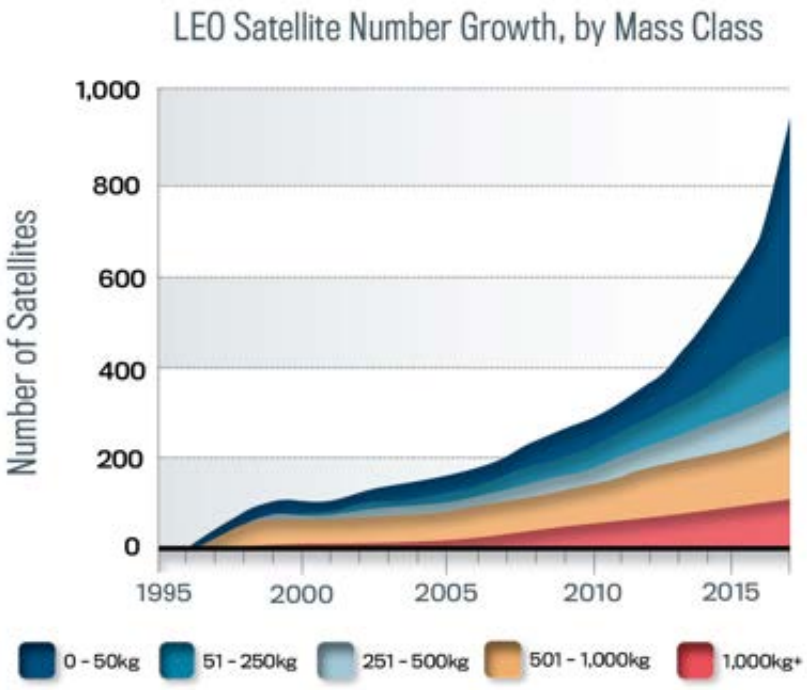
The market has shifted down to the nano or the CubeSats because they are cheaper, easier to build and cheaper to launch. It will be interesting to watch where the market goes with those three. Technology will continue to develop, and the disadvantage around nanosatellites is that they last only so long. Whether the market will shift into the middle area is something every pundit around the world is looking at, because they are working out launch capacity, for example, and what types of rockets they need to get the amount of satellites that are going to be needed in the future. Is it the constellation with the 100 satellites, which means a lot of launches; is it the geo, which requires one launch every little while; or is it in the middle, which is sort of the middle piece?[85]

82 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 2.

83 Professor Michael Smart, submission 13, p 1.

84 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

85 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, pp 9- 10.



Weight/class of satellites launched into Low Earth Orbit over 20 years [86]

Additionally, Mr Gilmour noted that large rocket companies are also seeking to significantly increase the number of launches per year to service commercial demand:

> *We have actually talked to other rocket companies—some of the bigger companies—that would be interested if there was a launch site in Australia. Kennedy are trying to ramp up their commercial launches to a few a week. They want to have capacity to launch two a day. That is their goal.*[87]

4.5 Investment in launch facilities

During the inquiry the committee repeatedly heard that any investment in launch facilities needs to be demand driven. Dr Dowse AO, Air Vice-Marshal (Retired), explained:

> *It needs to deliver value and have a viable source of revenue, whether that is from customers or parent contractors. This might seem obvious, but in the frenzy within the space agency there has been a lot of talk of doing things that have not been demand or revenue driven. Also, there are examples in the past. There have been a lot of satellite communications companies, especially in the low-earth orbit market, that have struck problems through a 'build it and they will come' approach, as presuming a future demand is a significant financial risk.*[88]

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86 Australian Government, *Review of Australia's Space Industry Capability, Report from the Expert Reference Group for the Review*, 2018, p 15.

87 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 16.

88 Dr Andrew Dowse AO, Air Vice-Marshal (Retired), public hearing transcript, Brisbane, 1 February 2019, p 11.

Mr Murfett from the Australian Space Agency highlighted the need for industry to develop the commercial case to support the development of Australian launch facilities.[89] Similarly, Dr Williams from CSIRO agued:

> *A number of people are looking at different launch sites, but for me that is very much a market issue.*[90]

The committee heard from Mr Wallis from Equatorial Launch Australia (ELA) who has developed a business case to establish the Arnhem Space Centre (ASC) in the Northern Territory. ELA's streams of business include:

- *ELA purchases flight proven third party launch vehicles and launches payloads into space for customers.*
- *ELA builds sites for Government organisations such as NASA, JAXA and ESA. ELA then leases sites and provides launch and support services.*
- *ELA builds sites to commercial customer requirements and provides launch and maintenance support.*

> *The ASC plans to offer support for all known launch technologies from traditional vertical launch (solid, liquid, hybrid and hypersonic), horizontal (aircraft) launch, balloon launch, sea launch and electric enabled launch.*[91]

ELA outlined that the company has agreements with European, US and Australian organisations for supply of low cost launch vehicles and operations. It is anticipated that European satellites/spacecraft could be launched from a dedicated ESA launch complex or ELA's commercial sites using ELA or European rockets. Commercial sub-orbital launches are expected to start in 2019 with satellites being launched in 2020.[92]

However, some industry witnesses highlighted the difficulty in making a business case for the development of launch sites by industry and consequently investment was required from government. Mr Green from PFI argued:

> *Four years ago I started working on a launch site proposal because I saw a huge link missing in the supply chain for that sort of industry... However, it soon became pretty evident to me that, even though the industry is very interested in investing in this sort of thing, there was no real economical way for industry to build such a facility—primarily from the lack of private land that can be purchased. Also, the business models around forming such a facility do not really lend themselves well to industry investment. The launch site itself is not really where the money is made in this sort of industry.*[93]

The committee heard that the investment in smaller launch sites[94] is minimal as these were 'basically a glorified shed, a concrete strip and some infrastructure to stand the rocket up'.[95] However, for larger rocket launches, such as those used by NASA, the biggest cost is allocation of land, as distances of upwards of 30, 40 or 50 kilometres need to be cleared and roads and associated infrastructure need to be constructed.[96]

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89 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, pp 6- 7.

90 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 18.

91 Equatorial Launch Australia, submission 19, p 2.

92 Equatorial Launch Australia, submission 19, p 2.

93 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 35.

94 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 5.

95 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 36.

96 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 36.

The committee was told that internationally, governments have invested in launch sites.[97] Witnesses to the inquiry argued that Rocket Lab received government funding to establish a launch facility in New Zealand and that this investment has produced benefits for the space industry in that country:

> *Only a few years ago, New Zealand was in a similar position to where we are right now. With an investment of $25 million from the New Zealand government, in this short period they have achieved realistic and beneficial goals and the company is now valued at over US$1 billion.*[98]

Rocket Lab Launch; Complex 1[99]

However, the committee also heard that the development of the Rocket Lab launch site was a complex commercial decision and that launch sites should be operated similarly to a railway station or airport, where infrastructure is used by multiple users on a fee for service bases. [100] Mr Gilmour noted:

> *I think they spent about $20 million—I am guessing—on that launch site. Peter Beck, who is the CEO, has come out and said he regrets doing that. It was not a good commercial decision. I do not think that is a good investment for a single company. The thing about a launch site is that it*

97 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 39.

98 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 22.

99 Source: Rocket Lab Launch: Complex 1, available at https://www.rocketlabusa.com/assets/Uploads/Still-Testing-8.jpg, accessed 5 December 2018.

100 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 15.

is like a railway station or an airport: it is not going to be used by just one company; it is going to be used by many.[101]

However, Dr Tirtey, Rocket Lab, did not support this approach and told the committee that launch facilities needed to be developed around the vehicles that will be launched from the facility:

A launch range is not a gas station where any rocket can come and you plug it in. It has to be developed around the rocket. You have to know, 'This is the rocket we are going to develop a launch range for.' The best example is SpaceX. They are probably the most successful launch company so far. When they go to Cape Canaveral they take it apart, they completely strip it bare to the concrete and then they rebuild it themselves, so they have this range built completely around their vehicle. It is not 'one range fits all vehicles'.[102]

Several witnesses argued that commercial investment was better spent on technology and employment of a skilled workforce:

It is not a good idea that one company pays the money for the launch site. If I look at my investable dollars, I do not want to invest dollars in infrastructure; I want to invest in technology and hiring smart people and developing world-beating technology rather than launch sites, which is more infrastructure stuff.[103]

The committee was told that a launch site facility would develop a co-located commercial ecosystem with the potential to created significant employment opportunities:

The Kennedy Space Center started opening up commercial areas around the launch site for commercial operators, and that has been hugely successful. Blue Origin has set up their main rocket-manufacturing factory about a kilometre away from the launch site. That might be a slight exaggeration, but it is really close. OneWeb, which is a very large small-satellite manufacturer that is putting up a thousand satellites in the next two years, has located in that park as well. I think this is a trend that is going to continue. I think it makes sense for companies to have their activities very close to the launch site… we believe at least a thousand jobs would result in the next five or so years from having a launch site in Queensland—high-paid, high-tech jobs that all of these university students can aspire to.[104]

4.6 Australia's sovereign capability

In addition to the commercial opportunities that domestic launch facilities would deliver, the committee heard that Australia currently relies on strategic partners for access to space applications of national significance and therefore is vulnerable to sudden geopolitical changes.[105] CSIRO have noted a:

… weakness of the Australian EO sector is that million-dollar Australian government programs and executing agencies are completely reliant on the health and continuity of the foreign owned and operated space assets, which provide the necessary imaging, positioning and data relay services, as well as the vagaries of internal data-policies, and budgetary cycles of operation countries.[106]

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101 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 19.

102 Dr Sandy Tirtey, Rocket Lab, public hearing transcript, Brisbane, 1 February 2019, p 25.

103 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 19.

104 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 15.

105 CSIRO, *Space, A Roadmap for unlocking future growth opportunities for Australia*, 2018, p 3.

106 Products for Industry, submission 7, p 2.

Professor Phinn from UQ provided an example of Australia's use of a foreign owned and operated space asset:

> *We have been very fortunate in our relationship with Japan in that for the last 40 years we get all our weather satellite data from Japan. That bilateral relationship is extremely important for supporting the meteorology bureau. The satellite which is up there now is collecting information and the highest repeat frequency is every two minutes, so you get an image every two minutes on the surface of the earth with one-kilometre pixels.*[107]

Dr Williams informed the committee that CSIRO had recently purchased a share of a radar satellite known as NovaSAR, which will provide Australia with some sovereign capability in relation to data to be used for scientific purposes:

> *This will be the first time Australia has full control of an earth-observing satellite. We [CSIRO] bought the data rights over Australia so that we could look at this radar satellite, which is all-weather, and allow scientists and operators to understand how it could benefit Australian business and industry and science. It is a particularly interesting one for the Queensland area because it is an all-weather system, so it can do the tropical zones. It can do water offshore. It is quite a broad-based satellite.*[108]

The Australian Defence Force relies on Australia's allies to 'provide situational awareness during operations, exercises and training, as well as to provide intelligence on the capabilities and activities of foreign organisations'.[109] The Defence Materials Technology Centre argued that the ability for Australia to put its own small satellites into low earth orbit in the Oceanic region would provide sovereign space capabilities and that Project 799 was investigating this capability:

> *The Australian Geospatial-Intelligence Organisation's Defence Project 799 (DEF 799) demonstrates the consideration the ADF is giving to sovereign space capabilities. DEF 799 is a $500 million investment to improve Australia's space-based ISR capabilities to support ADF operations. The program initially focuses on the acquisition of commercial satellite imagery, but Phase 2 will consider the possible acquisition of a sovereign geospatial intelligence space surveillance system, which would create significant opportunities for Australian companies in this sector in the 7 – 13 year timeframe.*[110]

Mr Blake, IALPG, highlighted the opportunity for Australia to increase its sovereign capability as satellites and launch vehicles become smaller, cheaper and more capable:

> *Australia has long relied on its relatively privileged access to the space infrastructure of its allies, especially the United States. That is as true in respect of civil space as it is in respect of military space, but there is a sovereign margin—a margin of Australian-specific needs—that is not met by access to the space infrastructure of allies. That margin is increasing. It is not increasing because of any growing differences with allies and partners but because space technology is changing and highlighting opportunities for us to do more for ourselves, especially as satellites and launch vehicles become smaller, cheaper and more capable.*[111]

Air Marshal McDonald, Chief of Joint Capabilities, Department of Defence, explained the situation from a Defence perspective:

> *Space is becoming more congested and more vulnerable to other players. Along with it comes opportunities. We are looking in the smaller domain such as cube satellites and rapid launch to*

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107 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 34.

108 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 11.

109 Defence Materials Technology Centre, submission 4, p 3.

110 Defence Materials Technology Centre, submission 4, p 3.

111 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 38.

cover perhaps any potential consequences of issues in space so that we can re-establish communications.[112]

In regard to launch facilities in particular, Air Marshal McDonald commented that there is a balance to strike between cost and control:

It might be nice to launch it at the cheapest site, but it may not be under your control. That is why we are closely looking at what is inside Australia that would potentially come out as a leader of small vehicle launch. Defence would not invest in it if it was not commercially viable. However, there is an element there where sometimes commercially viable is not the most important thing: it is that you own it and that you have control of it. Along with industry, we are trying to work out where those confluences may meet. [113]

Although Australia has a strong relationship with its allies in regard to space capabilities, Defence recognises that sovereignty is important. Air Marshal McDonald stated:

Sovereignty does not always equal Australian because of some of our very tight and close alliances. However, our sovereignty is very, very important. That is why we are investing in these capabilities in Australia as well. It also comes down to our ability to control what is going on and understanding clearly what we are up to and what others may be up to. That is where it is important for us to know what we are dealing with, why we are dealing with them and that we can rely upon them to deliver to Defence what we need.[114]

Dr Dowse AO, Air Vice-Marshal (Retired), also highlighted the importance of industry understanding the role and requirements of Defence when it comes to space. In his view, 'industry should be targeting both military and commercial opportunities, especially noting the commonality of both demand and, in many cases, technology.'[115]

[112] Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 3.

[113] Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 4.

[114] Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 10.

[115] Dr Andrew Dowse AO, Air Vice-Marshal (Retired), public hearing transcript, Brisbane, 1 February 2019, p 12.

5 Ground systems

Ground systems include ground segment operation of satellites and spacecraft.[116] The committee heard that ground systems communicate with spacecraft and satellites to both send and receive data.

Australia has a strong tradition of operating some of the most important ground systems in the world. CSIRO operates the Canberra Deep Space Communication Complex (CDSCC) on behalf of NASA, which has been delivering deep space communications from Australia for more than 50 years.[117] The Deep Space Network (DSN) consists of three deep-space communications facilities placed globally approximately 120 degrees apart: Canberra in Australia, Goldstone in California and Madrid in Spain. As the earth rotates, this placement permits constant observation of spacecraft and makes the DSN the largest and most sensitive scientific telecommunications system in the world.[118] CDSCC provides critical communications and tracking management of all NASA interplanetary space probes (around 40 missions), and is also involved in supporting missions from other space agencies on an ad hoc basis.[119]

DSS-43, Committee site visit to Canberra Deep Space Communication Complex, 20 November 2018.

116 London Economics, *Size and Health of the UK Space Industry 2016 – Summary report*, 2016.

117 CSIRO, submission 5, p 8.

118 Canberra Deep Space Communication Complex, Our Voyage of Exploration, available at https://www.cdscc.nasa.gov/Pages/welcome.html, accessed: 5 December 2018.

119 CSIRO, submission 5, p 8.

Dr Williams from CSIRO told the committee:

> *One or two of the highlights are that we operate in Canberra all of NASA's deep missions that go to the rest of the solar system. We operate all of the satellites—about 50 of them—for about eight hours a day... At the end of this year, one mission, Voyager 2, is set to leave the solar system. Australia is the only place that can monitor it as it leaves the solar system and look at the heliosphere. There is some very interesting science that goes on as a result of managing satellites.*[120]

The Australian Space Agency has identified space tracking, which covers space situational awareness—that is space debris monitoring, spacecraft tracking, telemetry and control as well as deep space communications — as one of its three national priority areas in the space industry. During the inquiry the committee heard that space situational awareness in relation to orbiting satellites and space junk was an important area and one in which Australia could play a leading international role.[121] The committee was informed:

> *When we get into orbit there is a lot orbiting up there, so it means that we need to pay attention to what is orbiting around the earth. Again, because of Australia's position we can see a lot of the sky and we have facilities around Australia that play a role in monitoring orbiting objects. That was once very much in the Defence realm of activities but, again, we now have more commercial providers that are launching their own satellites which means that they need data about what is orbiting around the earth. There are opportunities for commercial provision of those types of technologies or commercial entities providing those types of technologies to Defence, which monitors those activities.*[122]

Further, as more satellites are launched into space, there will be an increasing need to consider the impact of space debris and the responsibility and cost of removing such debris.[123]

Space tracking requires ground stations to receive and process spatial data. Ground stations located in politically and geographically stable locations are highly valued internationally.[124] Australia also has advantages due to its position in the southern hemisphere, its low light and low radio noise interference.[125]

At their most basic, ground stations comprise of two elements, an antenna and data processing centre. Air Vice-Marshal (Retired) Neil Hart explained:

> *One is the big antenna, which needs to be in a radio quiet area if it can. The data-processing centre does not need to be right next door but, as you start looking at some of the modern sensors that are pushing down terabytes of data, you do not then want to be pushing that over the ground over too long a distance. In proximity you would then have some sort of data exploitation and distribution.*[126]

Mr Kinne, Regional Director, Australasia, DigitalGlobe, explained how radar satellite constellations can downlink precise data:

> *The thing about radar as a constellation for observation is that it can see through clouds. It has some wonderful applications in change detection. It is a type of satellite that sends down a chirp*

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120 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 11.

121 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 34.

122 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 4.

123 Dr Andrew Dowse AO, Air Vice-Marshal (Retired), public hearing transcript, Brisbane, 1 February 2019, p 11.

124 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 6.

125 CSIRO, *Space: A Roadmap for unlocking future growth opportunities for Australia*, 2018, p 13.

126 Air-Vice Marshal Neil Hart (Retired), public hearing transcript, St Lucia, 19 October 2018, p 47.

and as a result it can measure that chirp coming back. If something changes on the ground, the chirp changes so it can be very clear about what has changed on the ground. It can report on subsidence. We have an asset that is 800 kilometres in space, but it can report on subsidence to a level of four millimetres.[127]

The committee heard that ground stations were necessary for satellites to downlink stored data:

The way a satellite works at the moment is that when it is on this side of the earth or over the Antarctic or something it just stores all the data on-board. They do not have unlimited storage. They can be selective as that data starts to get full. As soon as it is within sight of a ground station it squirts as much data as it can down to that ground station and tries to get it off so that it can then start uploading new data.[128]

In comparison to Australia's Asia neighbours there is limited ground station infrastructure in Australia.[129] Consequentially, Australia is reliant on international partners to downlink satellite data. Air Vice-Marshal (Retired) Neil Hart told the committee:

Some of our images are downlinked through Alaska, Toulouse in France or various other sites, and it can take 24 to 36 hours for those images to come back to Australia once they are downlinked, processed and then pushed back through the internet. If we were to have some ground facilities and data processing here in Queensland, potentially you could be processing and providing those images within minutes rather than days. Now you have really fresh images that could be used for a number of safety and other applications rather than the time delay that you see.[130]

Additional ground stations within Australia could deliver faster response rates in the provision of satellite data and address the downlink bottleneck which currently exists over Australia.[131] Further, CSIRO noted:

Australia's geographic location makes it a strategically important location for downlinking of large amounts of Earth observation satellite data. When combining Australia's land surface, marine areas and our Antarctic territory, we have oversight of almost 1/8th of the Earth's surface.[132]

127 Mr Peter Kinne, public hearing transcript, Brisbane, 16 November 2018, p 30.

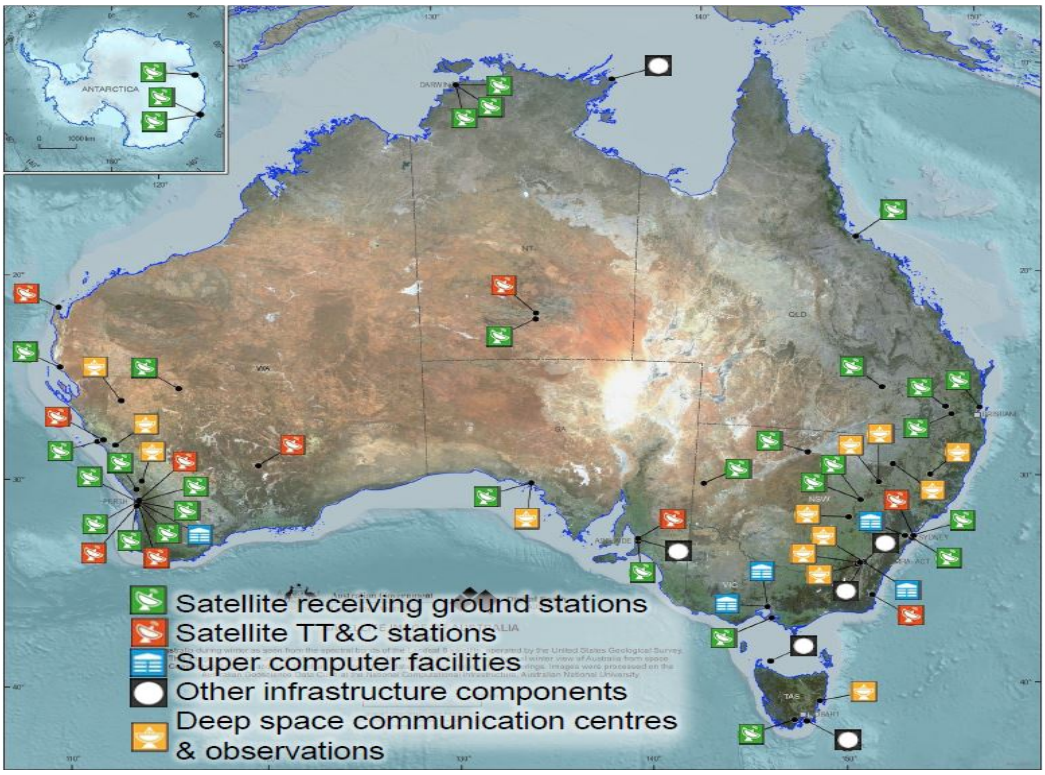
128 Air-Vice Marshal (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 48.

129 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, pp 31-32.

130 Air-Vice Marshal (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 45.

131 Air-Vice Marshal Neil Hart (Retired), public hearing transcript, St Lucia, 19 October 2018, p 48.

132 CSIRO, submission 5, pp 6-8



Map of Australia's space-related infrastructure[133]

Mr Kinne from DigitalGlobe provided an example of the advantage that locally available ground stations could provide:

> *For example, if somebody wants to look at frost damage within a particular region, at the moment we would require that commercial order to happen 24 hours prior to the satellite coming over, at a bare minimum. Typically we would want it to be much earlier. If we have a local ground station network, we could be looking at turnarounds much more frequently than that to place the order, because you are buying satellite minutes; you are buying access to that satellite in that orbit. You have the ability to task, download and distribute that data within that same orbit environment. It becomes a very fast response and gives you access to, I think, benefits not only in agriculture but also in emergency response—the whole series of responses that the government may want to partake in.*[134]

Ms Starkey, CEO and Founder of Ozius, explained that it is important to consider the demand for fast data in addition to the potential 'bottleneck' of data as more satellites are launched:

> *The advantage of ground stations locally is that we can get to data faster. However, again, that need must be driven by the need for fast data, as well. A lot of our clients are happy with 48- to 72-hour turnarounds, but I do see advantages in that with more satellites going up there is going to be a bottleneck at some point. Therefore, it is about being able to provide more local options to make sure that Australia is getting the data that we need and that we are not getting a backlog as the satellites pass over and head into the northern hemisphere for more collections.*[135]

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133 Source: Mr Trevor Power, Department of Industry, Innovation and Science, *The Australian Space Industry: The Australian Government perspective,* April 2018, original image Australian Government, *Review of Australia's Space Industry Capability: Report from the Expert Reference Group for the Review*, March 2018, p 21.

134 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, pp 31-32.

135 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 20.

A number of submitters highlighted that the limited access to bandwidth significantly constrains the downlink of data. As a result major research institutions, such as CSIRO, are investigating automated processing on-board satellites:

> *It currently is a logjam in two ways. The current model is for satellites to send data down to the ground, it is received and then it is processed, let us say, by a small company or the state government and then people can access that off a website. You need bandwidth to have the website and bring that information across to look at the website or to generate a report for your phone. There is a bit of a block to begin with, and as we start getting more and more sources of information there is more and more data coming on. One of the areas we are looking at research-wise at the moment … is on-board processing: building satellite systems which are targeted. Let us say you built one specifically for the sugarcane industry or for wheat globally. It collects data in specific colours or wave bands that work, let us say for wheat, and lets you look at wheat yield, applies the algorithm on the satellite and then it sends down. Instead of petabytes and gigabytes you are now talking about hundreds of bytes at a time of information which could go straight to a computer as a simple map, or it could be a text alert.*[136]

Air Marshal McDonald, Chief of Joint Capabilities, Department of Defence, also told the committee that there are technologies available that can assist with the challenges associated with bandwidth:

> *…we use a variety of the spectrum—from HF satellite communications to line of sight and we always balance that. There are technologies emerging and in existence that assist with those challenges. At the moment, we are not necessarily constrained by bandwidth. It is talked about a lot and people say that we will be overwhelmed by the requirement but, as yet, that has not necessarily eventuated. As I said, there are new technologies emerging that can quickly sidestep that and provide other avenues.*[137]

The development of additional ground stations would not only provide benefits in terms of downlink times of satellite data and the ability to prioritise tasks in real time, but locally based ground stations would also provide significant opportunities for developing and supporting a range of commercial opportunities:

> *I think the main employment is not the antenna … even though we are focused on that. The main employment is that whole ecosystem. It is the data centre, the analytics hub, the cluster, the R and D, the commercialisation and servicing our local industry or international industries.*[138]

The co-location of interrelated space industries in a satellite park or the establishment of companies within that ecosystem in Queensland was highlighted in the evidence. Satellite parks in Queensland would facilitate partnerships which support the many aspects of the value supply chain, of which ground stations are just a part.

> *When we look at and talk about ground stations, we should interpret that as ground stations, data centres, innovation hubs or clusters, some R and D component, the commercialisation of that, and looking at the industries that can be improved or impacted by that the most, which is, of course, agriculture, mining and the environment—key industries for the Queensland economy.*[139]

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136 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 30.

137 Air Marshal McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 9.

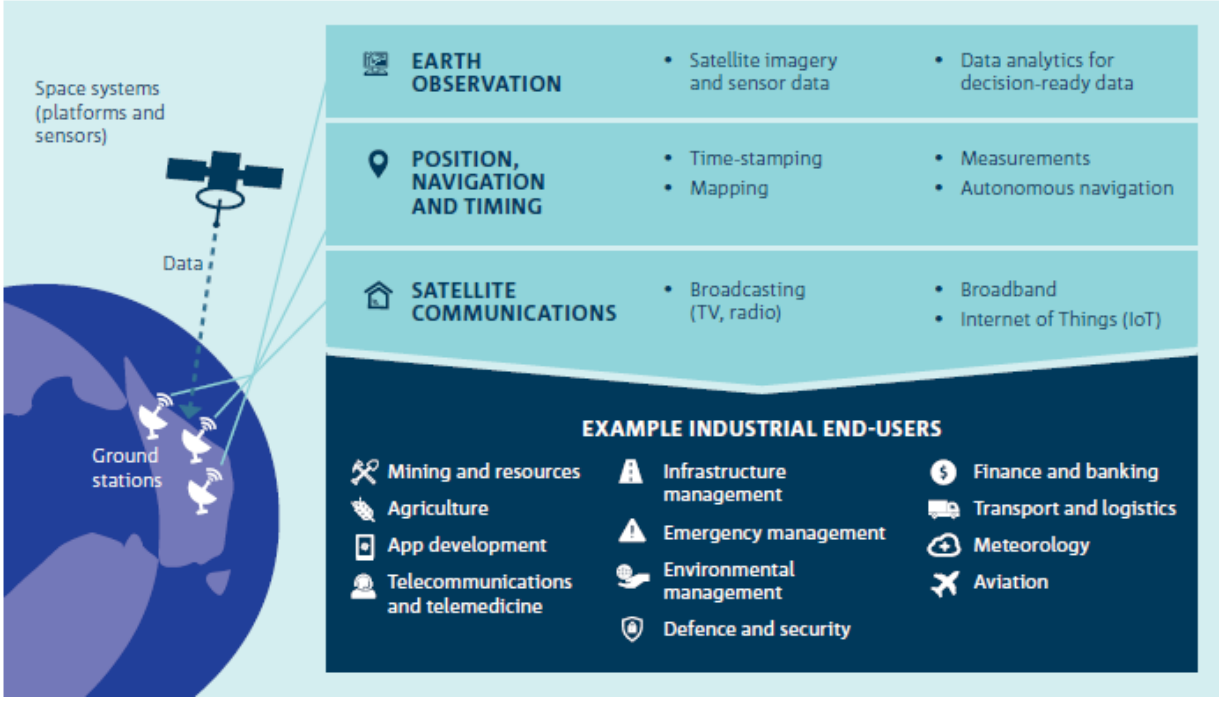
138 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 33.

139 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, pp 31-32.

6 Space industry products and services

6.1 What the space sector produces

Space based systems create an array of everyday services including, broadcasting, fixed and mobile satellite communications services, processing satellite data from earth observation, location-based services and GPS such as position, navigation and timing.[140]



Opportunities for space derived services[141]

6.2 Earth Observation

During the inquiry the committee received significant evidence on earth observation (EO). EO data provides regular observations of physical, chemical and biological systems over large geographic areas and extended periods of time. The committee heard that:

> *Earth observation, or remote sensing, is any activity where we collect information about the earth, its atmosphere and oceans from satellite, aircraft and also remotely piloted systems. This activity underpins the collection of geospatial or geographic information, which is essential for pretty much all levels of government, from local to state to Commonwealth, in Australia.*[142]

After communication services, EO is one of the three central industries that underpin Australia's current and future space activities and is the space sector with the highest predicted growth in Australia and globally over the next five and ten year periods.[143] The value, demand and application of EO data has increased significantly.[144]

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140 London Economics, *Size and Health of the UK Space Industry 2016 – Summary report,* 2016.

141 Source: CSIRO, *Space, A Roadmap for unlocking future growth opportunities for Australia*, 2018, p 7.

142 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 27.

143 Professor Stuart Phinn, submission 10, p 1.

144 Professor Stuart Phinn, submission 10, p 1.

The committee was informed that access to satellite information, while available for a number of decades, was limited due to its expense, low resolution and infrequent rate of data downlink. Mr Jacoby, Executive Director, Land and Spatial Information from the Department of Natural Resources, Mines and Energy (DNRME) highlighted the increased availability of EO data due to developments in satellite technology and as a result of Space 2.0:

> *These new CubeSats that… we are now utilising basically scan the planet every day, and Queensland has been making use of that imagery. We get a daily image... That trend will continue. The systems will get cheaper and more frequent, and I think we will see them move into providing video and not just imagery. You have the opportunity to look at any part of the region in real-time video or high-resolution imagery across a number of spectrums. This can be game changing for many applications within the state.*[145]

6.3 Earth Observation applications

EO information and products are routinely applied across a wide range of industry sectors. Professor Phinn from UQ noted:

> *The use of this type of imagery and the information derived from [EO] is rapidly expanding across all sectors of industry and all levels of government. I think some examples you are aware of are that it underpins our daily weather and oceanographic forecasts, disaster management systems, water and power supply, infrastructure, monitoring and operation for defence and mining, agricultural production and environmental monitoring.*[146]

Examples of applications of EO are found in:

- bushfire mapping
- emergency and disaster prediction and response
- energy resources
- flood mapping
- forestry
- horticulture
- infrastructure
- land management
- ocean monitoring
- mining and mineral exploration, including mine site rehabilitation
- agriculture, including precision agriculture
- research
- urban and regional planning
- water resource management
- weather forecasting
- environmental monitoring
- asset management
- transport route design and maintenance[147]

[145] Mr Steve Jacoby, DNRME, public briefing transcript, Brisbane, 15 October 2018, p 11.

[146] Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 27.

[147] Earth Observation Australia, submission 6, p 4.

Dr Williams, CSIRO, outlined that as a result of developments in satellite technology, high spatial resolution imagery had improved significantly allowing the development of valuable applications:

> *In the early satellites, because of the limitations of bandwidth and the technology of sensors, you would predefine the bandwidths that you looked at. Most of the early ones had a red, a green and a blue so you could make a colour picture and maybe an infra-red to look at the edge and a thermal to look at temperature. Now we are moving to what we call a hyperspectral, where you can look at any part of the spectrum but you have on-board processing to choose which part you look at with any particular application. If you are flying over water, you may change the boundary conditions compared to over land… You would change the frequencies you observe in almost real time on the satellite with hyperspectral to look at the bandwidths you wanted to look at.*[148]

Mr Kinne from DigitalGlobe provided an example of the level of spatial resolution imagery currently available from radar satellites, 800 kilometres in space:

> *… we are able to identify every tree, the height of every tree, the size of every tree, where the grass was, where the driveways were, how big the roof is, how high the roof is at each eave as well as the complexity of the roof, whether the roof has solar panels or whether the building has a swimming pool.*[149]

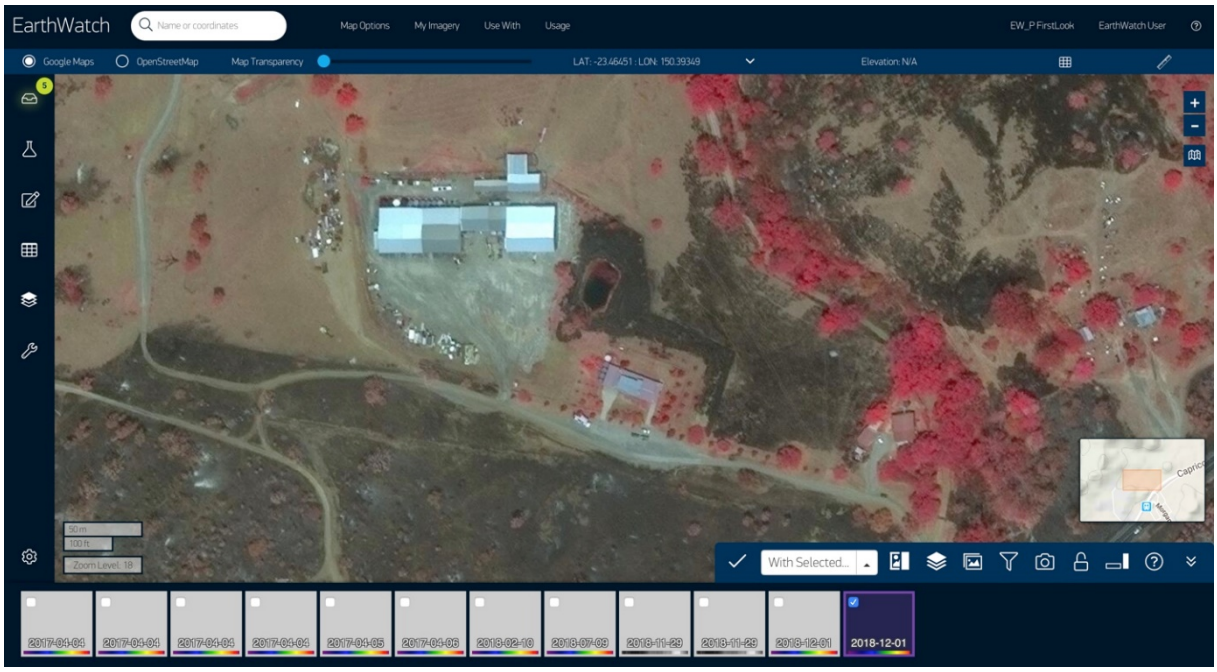
Additionally, Mr Kinne explained:

> *There are five satellites currently on orbit from a DigitalGlobe perspective, and MDA owns and operates Radarsat. Those satellites have various spectrums from RGB, which we are all familiar with—we see in RGB: red, green and blue—right up to 16 channels, which includes short-wave infra-red. A really exciting part of it is the various wavelengths… there is a channel between the colour red and visual/near infra-red, which is called red edge. Red edge is very specific because it reflects off plants that are undergoing photosynthesis. If you see a plant that is green and it is not reflecting in red edge then it may be poisoned, dead or whatever. We can actually tell the health of a plant from space.*[150]

148 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, pp 15-16.

149 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 31.

150 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 31.



Satellite imagery provided by DigitalGlobe[151]

The Defence Materials Technology Centre highlighted the beneficial synergies between defence technologies in EO and their use in a civilian context:

> *A secondary, but still significant, consideration in relation to space-borne technologies is that the sensing and earth observation capabilities desired by Defence have potential dual-use application in response to civil/commercial challenges. For example, space-borne hyperspectral sensors can be used to derive information significant to amphibious combat but can also be used to remotely monitor the health of food crops. The ability to extract and classify military targets of interest from a real-time data stream is equally useful when inspecting large pieces of civil infrastructure such as the national power grid.*[152]

Under Space 2.0 the increasing number of satellites has resulted in the substantial generation of data and therefore greater opportunities for EO applications:

> *It is that generation of the intellectual property about turning the images from pictures into a map of, if you are looking at mangoes or avocados, estimated crop yield or tree height—or if you are looking at dams, water quality... Where there is opportunity for industry is in building that information delivery, so you are delivering information specifically for certain agriculture applications, horticulture, infrastructure monitoring and mining. It is that expertise that the state government has for some natural resource management, but we are seeing the emergence of smaller companies that are doing that in association with certain, let us say, growers in a certain type of horticulture.*[153]

151 Source: Mr Peter Kinne, DigitalGlobe, correspondence dated 11 December 2018.

152 Defence Materials Technology Centre, submission 4, p 4.

153 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, pp 30-31.

The committee heard that the Department of Natural Resources, Mines and Energy has significant experience in developing applications from high spatial resolution imagery.[154] Professor Phinn, UQ, told the committee:

> *The work that is going on in the Department of Natural Resources, Mines and Energy is delivering high spatial resolution imagery to support state and local government applications across the entire state. Basically, they signed a world-leading agreement with Planet, one of the new space companies, to deliver this high spatial resolution imagery on a regular basis across the state. That is where we are now looking at pixel sizes of around three to four metres, with that information being collected four to five times a day and it is potentially accessible and useable. That agency has built capability to collect that information and turn it into decision-ready information.*[155]

CSIRO also has significant expertise in the development of algorithms for analysis of very large-scale Earth observation datasets.[156] In the private sector, start-up companies are building the algorithms to develop applications on a pay-for-service basis.[157] An example is Ozius, a Brisbane-based earth observation analytics company. Ms Starkey from Ozius explained how earth observation forms part of the downstream space ecosystem:

> *There are three fundamental steps involved as we form part of the downstream analytics part of the space ecosystem. We acquire the raw earth observation data from various satellites to meet the customers' needs. We take our customers' existing on-ground data and information that they have been collecting for years, maybe even decades, and we bring it all together using our own proprietary analytics to create new knowledge about their operations.*[158]

Ms Starkey further explained that Ozius adds value to the data it obtains, assisting customers with their immediate problems and helping them to improve management decisions in the future:

> *To be clear, Ozius is not in the business of providing data. We are in the business of providing our customers with answers. We use the vast archives of earth observation data available, and we can go back in time to fill gaps in knowledge. By filling gaps in knowledge, we reduce assumptions which improves decision-making today, and predictive analytics helps forewarn and forearm decision-makers against the challenges of tomorrow.*[159]

This type of information has been used, for example, to measure how the environment functions prior to a mine opening in order to benchmark the success of future rehabilitation. It has also been used to help scientists discover groundwater fed springs that no-one knew existed previously.[160]

The committee heard that internationally many governments provide EO data as open source data in order to stimulate the development of EO applications. Dr Williams from CSIRO outlined:

> *The challenge is whether you charge for the data or make the data open source. Europe has gone open source. The US primarily in the government sector is open source and the commercial operators are trying to go closed source. The challenge there is that the data itself has a value but you cannot just pick it up and use it. It is the modelling and how you integrate it and how you perceive it that gives it value.*

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154 Mr Steve Jacoby, DNRME, public briefing transcript, Brisbane, 15 October 2018.

155 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 29.

156 CSIRO, submission 5, pp 6-8.

157 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 31.

158 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 18.

159 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 18.

160 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 18.

… open source is probably the way to go for a while to allow the bright people who understand the satellite data and understand the application area to develop real applications which they then sell for a value.[161]

The increase in available EO data provides both opportunities and challenges for Australia. CSIRO has noted that:

There are significant challenges, however, in terms of the acquisition, processing, analysis and integration of these rapidly increasing large, robust critical datasets. The Australian Government currently spends around $100 million per annum on Earth observation from space and associated data processing. There are over 100 active federal and state government programs, representing a further government investment of about $950 million, with direct dependencies on Earth observation data estimated to contribute more than $3.3 billion per annum to GDP.[162]

6.4 Ancillary services

Ancillary services include those support services for launch and satellite services, financial and legal services, software and IT services, market research, consultancy and business development.[163]

The committee heard from International Aerospace Law & Policy Group which is a specialist law practice focused on aviation and space law, maritime, and Defence. IALPG highlighted that:

Facilitating or identifying novel ways to provide space companies with professional services will enable other sectors of Queensland to participate and benefit from the progress of the space industry. These could be focused on providing professional services including accounting, corporate advice, legal, and so on that will support new ventures in setting up businesses, navigating the legislative/regulatory approval process (some of which are still being developed), protecting intellectual property rights, and fostering collaboration with other Australian space industry participants.[164]

During the inquiry, protection of intellectual property was identified as an area in which space focused start-ups have limited knowledge.

They do need some help with intellectual property, especially in respect of commercialisation, because small start-ups are going to partner with others that want their piece of the intellectual property pie. There is always a question of how to divide up the intellectual property between the brand-new start-up and whoever is assisting or funding them in some way.[165]

Mr Wheeler, IALPG, identified a lack of professional service support to the aerospace sector:

Generally, there is a dearth of professional services accessibility for start-ups, definitely in the aerospace sector. It is something that is generally provided by innovation hubs, accelerators and those sorts of programs, but not everyone is involved with those. It is something that we have seen requires some strength of support.[166]

6.5 Future users and customers

The space supply chain terminates with the end users who consume the products which are generated by the space industry. The committee heard of several Queensland developed EO products for the

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161 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 17.

162 CSIRO, Earth observation and informatics, available at: https://www.csiro.au/en/Research/LWF/Areas/Landscape-management/Earth-observation, accessed 13 December 2018.

163 London Economics, *Size and Health of the UK Space Industry 2016 – Summary report*, 2016.

164 International Aerospace Law & Policy Group, submission 20, p 3.

165 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 41.

166 Mr Joseph Wheeler, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 41.

agricultural sector. An example is DataFarming, a Toowoomba based company that has developed EO applications that look at the condition of crops from space to predict yield. This allows businesses to plan for how many people are needed to harvest and more accurately purchase the number of packing supplies, and to consider the transport logistics. This application prevents overspending or underspending in a business.[167]

The development of real-time video or high-resolution imagery can also translate into a product that monitors personnel travelling long-distances. For example, Mr Jacoby from DNRME explained:

> *Potentially for our department the most dangerous thing we do is put public servants in vehicles and have them travel large distances. Knowing that they are safe through techniques like personalised monitoring or giving them the intel they need before they visit a property, whether it be conducting compliance activities in vegetation management or in water monitoring or the valuation of remote properties, giving them the intel in advance through satellite systems, earth observation and positioning makes our department and the service far more effective and makes us a far more responsive government.*[168]

With the development of significant EO applications across a wide range of industries, the committee heard that there was an increasing need to communicate this to end users:

> *Helping those traditional industry sectors come to grips with the new opportunities that space brings will bring tremendous opportunities. Whether it be in agriculture or in areas such as natural disasters and how we more quickly recover through the use of earth observation, or keeping people safe in times of disaster through personalised monitoring, that can all be enabled through space. Those are tremendous opportunities for the state to develop. We will need to work at translating those opportunities from the space industry into the traditional sectors.*[169]

[167] Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 30.

[168] Mr Jacoby, DNRME, public briefing transcript, Brisbane, 15 October 2018, p 11.

[169] Mr Jacoby, DNRME, public briefing transcript, Brisbane, 15 October 2018, p 10.

7 Queensland's capability to support a space industry

Throughout the inquiry the committee heard that Queensland has a number of strengths to make a significant contribution to an Australian space industry:

- Queensland companies are already developing launch vehicles and propulsion systems
- Queensland's geographic position makes it well suited for the development of a launch sites and associated space industry hubs
- Queensland offers ideal locations for a ground stations or satellite parks
- there is a natural cluster of earth observation activities in Queensland
- Queensland has a significant number of companies already active in the space supply chain, in addition to a workforce skilled in related industries such as manufacturing and technology, mining, aviation and defence
- the state is home to strong research institutions that produce talented graduates in space-related fields
- Queensland students are actively involved in STEM education.

A common theme amongst the evidence was that for Queensland to play a role in the Australian space industry, the state needs to focus on niche areas of competitive advantage.[170]

7.1 Queensland's capacity to develop launch vehicles

Queensland has a number of research and commercial entities developing launch vehicles for small payloads - for example, Gilmour Space Technologies, Hypersonix, and Black Sky Aerospace.[171]

Gilmour Space Technologies has acquired $24 million in venture capital to develop launch vehicles and a unique propulsion system. The company has suborbital launch capabilities.[172]

One Vision Rocket, Committee site visit to Gilmour Space Technologies, Pimpama, 1 February 2019.

[170] Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

[171] Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, pp 2-3.

[172] Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018.

Hypersonix is a start-up company that has been developed through UniQuest, UQ. Researchers from the Centre for Hypersonics have joined with local Queensland SMEs to develop re-usable hypersonic engines called scramjets. UQ is developing a small satellite launch system called SPARTAN.[173]

> *With the SPARTAN system, we call the fly-back first-stage rocket booster the Boomerang, because it flies back to base and lands right next to where it was launched. The hypersonic stage that is powered by a UQ designed scramjet—which … can heat up to 1,500 degrees Celsius on the way to space, before returning to base—is the second stage of the system. The only part of the system that is expendable is the small upper stage.*[174]

Black Sky Aerospace is another Queensland-based company whose services include launch vehicles and propulsion systems. Black Sky Aerospace operates the only commercial suborbital launch site in Queensland, which allows the company and its partners to develop, test and operate systems and vehicles.[175]

Black Sky Aerospace Launch vehicle Committee site visit to sub-orbital launch, Tarawera, 21 November 2018.

173 Professor Michael Smart, submission 13, p 3.

174 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, pp 2-3.

175 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018.

Committee comment

The committee notes that Queensland is home to a number of companies that contribute to the development of launch vehicles, including the companies that develop the vehicles and those that contribute through their manufacturing, technology and research expertise.

Recommendation 1

The committee recommends the Queensland Government facilitate and encourage the continued development of launch vehicles in Queensland.

The committee heard from these companies that in order to support the development and manufacture of launch vehicles in Queensland, there was an urgent need to develop a Queensland launch site.

7.2 Queensland's suitability for launch sites

The committee heard that Queensland has a number of natural advantages which are well suited to the development of launch sites. Queensland's geographic position, covering wide open spaces in the west and a long eastern coast, provides for both polar and equatorial launches. [176] This geographic position also allows for a 'general purpose' site, similar to the Kennedy Space Centre, as the latitude of Brisbane is within approximately one degree of latitude to Cape Canaveral, Florida.[177] Professor Smart, UQ, explained:

> *Whilst launch sites close to the equator suit low inclination orbits, and launch sites far from the equator suit high inclination orbits, a general purpose launch site can benefit from being "in between". Such is the case with Florida in the US.*[178]

According to Mr Gilmour, Gilmour Space Technologies, there is almost no other place on earth that has the same flexibility that Queensland offers in this respect. [179] Mr Nikolic, Black Sky Aerospace, similarly commented that Queensland's geographic features provide industry with a wide variety of launch options.[180] A key feature of Queensland's geographic position is the ability to provide for launches in an easterly direction.[181] Mr Gilmour explained:

> *When you launch a rocket you have to launch towards an easterly direction because the earth spins that way. The pickup that you get from the spinning of the earth is up to about 460 metres a second, which in relative terms is almost 1½ times the speed of sound... If you launch that way, you get a slingshot effect. It is way better to launch east than west. The closer you are to the equator, the closer you are to having that slingshot effect take place.*[182]

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176 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 39.

177 Air Vice-Marshall (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 46.

178 Professor Michael Smart, submission 13, p 5.

179 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

180 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 25.

181 See, for example, Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 4; Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 39; and Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

182 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

Professor Smart, UQ, also outlined the commercial benefits of the 'slingshot effect':

> *The great thing about the east coast is that the earth is spinning easterly, so when you launch easterly you actually get a kick from the earth and you can launch more payload for the same rocket. Going westerly is just more complicated and you can get less performance, essentially, from the same rocket.*[183]

Queensland's capacity to provide for easterly launches over the ocean is also considered an advantage because such launches avoid populated areas and other countries, thereby decreasing risk.[184] Dr Tirtey, Rocket Lab, explained that low air and maritime traffic was a crucial factor in Rocket Lab's decision to launch from Mahia, New Zealand. Dr Tirtey stated this allows Rocket Lab to fly every 72 hours, more than all of the sites in the United States put together.[185]

However, some witnesses noted that launches from the Queensland towards the east raise the issue of possible damage to the Great Barrier Reef from discarded rocket motors and other debris. Consequently, the committee heard from some stakeholders that the Great Barrier Reef should be a 'no-go zone'.[186] For example, Mr Nikolic, Black Sky Aerospace, explained the risk of fragmented debris that may be difficult to recover:

> *If you get one large piece that lands in the ocean, you might be able to go and pick it up and that is great, but if you do not how do you then accommodate all those fragments that may have landed somewhere? Ideally, in a perfect world you do not have that, but we have the reality to deal with*.[187]

Other stakeholders considered that the risk to the Great Barrier Reef was manageable. Professor Smart, UQ, told the committee that it was an environmental consideration that could be managed, for example, through a requirement that relevant parties remove debris or use re-usable launch vehicles.[188] Mr Gilmour, Gilmour Space Technologies, considered the risk to be minimal and explained that trajectories can be managed to avoid damage:

> *Rockets are very precise vehicles….You can analyse trajectories and you can even modify your flight inclination to make sure that your rocket will not land on the Great Barrier Reef. We have done that analysis already. I would think that, using probability analysis, there would be about a one in 10,000 or 100,000 chance of anything on our vehicle or a similar vehicle hitting the reef.*[189]

Tourism and air traffic were also raised as matters to consider when launching over the Great Barrier Reef. Mr Nikolic explained that the 'J' route (from Cairns to South Australia) is one of the busiest routes in Australia for air traffic and that in developing launch sites, issues such as air traffic, sea traffic and tourism need to be taken into account.[190] Mr Green, Products for Industry, explained some of the potential impacts on tourists if airspace needed to be cleared over the Great Barrier Reef:

> *If we were planning to launch over the Great Barrier Reef, we would have to clear people out of a very large section of the Great Barrier Reef, and that would have a huge impact on tourism. If*

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183 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 5.

184 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 4; Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 13.

185 Dr Sandy Tirtey, Rocket Lab, public hearing transcript, Brisbane, 1 February 2019, p 24.

186 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 24.

187 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 24.

188 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 9.

189 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 18.

190 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 24.

I try to book out a day when they are not going to be there and then I miss that window and I try to do it the next day, international people trying to book a trip there would then be severely inconvenienced. It becomes something that, as a business model for the state, is not a very good option.[191]

However, the committee also heard there are parts of coastal Queensland, particularly in regions north of Brisbane such as Gympie, where there is a significant amount of clear airspace which could be utilised for launches.[192] Some of these areas also have Defence controlled airspace, which makes launching easier to manage.[193] Professor Smart, UQ, noted the advantages of Defence controlled and low-use airspace in Queensland.[194]

The Department of Defence sees the potential for a launch site to be established in Queensland, but advises that it is currently monitoring the local industry:

We understand the complexities of trying to stand up something like this. It is big money and trying to get the return is difficult because of the competition in the global market. New Zealand is very active and everyone wants to get a part of it. Payload costs have reduced significantly around the world. That will cause a tension in the market that will either sink some or make some very competitive.

Going back to our geographical location, we are in a box seat there for launch. Our stability as a nation is highly prized. The majority of projects that we currently have are still in the define requirements phase. That is why we are actively monitoring who is about in the Australian industry, in the states and particularly in Queensland, so that we can best understand how to go forward. Because we are not engaging really closely that should not be seen as an indication that we are not interested. To be definitive is not something that we can do at the moment.[195]

Mr Blake, IALPG, proposed that Queensland could take a staged approach to the development of a launch facility:

Queensland's part in those comprehensive solutions could be developed iteratively, starting with a test site for the development of launch technologies and progressing quickly to the establishment of an orbital launch facility at the same site or elsewhere, building on experience from the test site. Such a test site could concurrently host the sorts of space enterprises that need to be hands-on with equipment in order to develop their technology.[196]

Mr Nikolic, Black Sky Aerospace, similarly commented:

Going back to the discussion about launch sites and infrastructure, that is probably a major component for the Queensland Government to look at—something that can benefit the industry as opposed to an individual. That investment would be able to facilitate things like testing. That is a lot of what we actually do, but it can upscale those processes. As we continue to develop our systems, we need more infrastructure like that for testing. If the launch site came to fruition with the government owning that or an organisation that is run by industry as opposed to an individual—and when I say 'individual' I mean company or person—owning that, those are the

191 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 35.

192 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 5; Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 17.

193 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 5; Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 37.

194 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 8.

195 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 8.

196 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 39.

> *sorts of investments that in the early stage would help kickstart a lot of the industry for Queensland.*[197]

Committee comment

The committee considers Queensland's geographic conditions to be an advantage when considering the development of a launch site and acknowledges the evidence from industry that a launch site would benefit multiple industries along the space supply chain. In particular, the committee notes that Queensland has a number of companies that develop launch vehicles and that a launch site would encourage these companies to remain in Queensland and potentially expand as the industry develops.

A launch site in Queensland would provide opportunities for companies to launch their vehicles from Queensland, but also promote the development a co-located commercial ecosystem around the site to incubate and accelerate businesses in the space industry.[198] A commercial ecosystem around a launch site could also attract businesses to Queensland, such as satellite manufacturers. The committee considers that a launch site and a co-located commercial ecosystem has the potential to create significant employment opportunities, particularly for regional Queensland.

The committee notes that the Queensland Government is currently investigating potential launch sites in Queensland and that the department has commissioned a feasibility study into the siting options available in Queensland for a satellite park and a launch facility.[199]

The committee considers that the development of the space sector in Queensland will be enhanced by launch facilities in Queensland. The committee considers that any proposal to develop launch sites should be informed by the departmental feasibility study into the siting options available in Queensland for a launch facility, currently being undertaken.

Recommendation 2

The committee recommends that the Queensland Government develop siting options available in regional Queensland for a launch facility to provide the launch component of the space industry supply chain.

7.3 Queensland's suitability for additional ground stations or satellite parks

Queensland is considered by industry to offer an 'ideal location' for ground stations.[200] Queensland's large land mass and position along the eastern coast of Australia allows for the capture of a wide range of data from space.[201] In addition to offering access to satellite data from the eastern coast and Pacific, Queensland provides access to satellite data covering regional and central Australia.[202] Mr Kinne, DigitalGlobe, explained:

> *The location gives it a good view to the horizon and the cone, or coverage, of the view of the satellite as it comes into that orbit extends across the whole eastern seaboard of Australia out to the middle of Australia.*[203]

197 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 22.

198 See section 4.4 of this Report.

199 DSDMIP, submission 16.

200 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 33.

201 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 5.

202 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 33.

203 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 33.

The committee was informed that the Queensland Government is currently investigating potential sites for additional ground stations:

> *I think from a government point of view it would be about finding a location that is radio quiet, is close to fibre-optic links, has dry conditions et cetera. It would probably be a case of finding the site and then trying to encourage commercial people to then locate various antennae and other ground stations in that location.*[204]

Air Vice-Marshal (Retired) Neil Hart informed the committee that the Sunshine Coast, just north of Brisbane, was well suited to situating ground stations due to several factors:

> *It is probably worth adding the ground station element, which we are doing as one of the studies. Off the Sunshine Coast somewhere is about halfway between the top of Cape York and the bottom of Tasmania. With a ground station in sight of the satellites you can get that downlink of information that would be able to see a large swathe, almost from New Zealand to New Guinea and out into the Pacific. Queensland has that geographical advantage even in that data delivery, if you like, that we need to have a look at.*[205]

Queensland's extensive coverage will have commercial benefits for end users involved in a variety of sectors, such as environment, mining and agriculture.[206] The new international broadband submarine cable into the Sunshine Coast will provide Australia's fastest telecommunications connection to Asia and second fastest to the United States, and will provide Queensland with additional capability to analyse and process the data received from space.[207] Construction has begun on this $35 million project, which is jointly funded by the Queensland Government ($15 million) and the Sunshine Coast Council ($20 million).[208] The department advised that the cable will provide a data pipeline and high speed 'Internet of Things' connectivity that are required for Space 2.0.[209] Ms Johnston, DSDMIP, stated:

> *The opportunity from a space perspective is that the volume of data being collected is growing to a very significant scale and you need the mechanism to process that data. Having the additional line coming into the Sunshine Coast provides Queensland with a more viable opportunity to transmit the very large volumes of data that are being captured by space.*[210]

This fibre optic cable will add to the capabilities of the existing high-speed data cables along the east coast of Australia and provide resilience to the system.[211] It will also offer an alternate route for global companies and research institutions to send large packets of data domestically and internationally, in particular, to Asia.[212]

Ms Starkey, Ozius, confirmed the importance of a fast internet connection for the transfer of data and information, which is relevant to all aspects of the space supply chain:

> *It is a very connected system right from the launching of the hardware through to coming down to the ground stations and then into our offices and into the customers' hands, who can then make their decisions based on our information. At any one of those points, if there is a disconnect*

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204 Air Vice-Marshal Neil Hart (Retired), public hearing transcript, St Lucia, 19 October 2018, p 48.

205 Air Vice-Marshal Neil Hart (Retired), public hearing transcript, St Lucia, 19 October 2018, p 46.

206 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 33.

207 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3

208 Queensland Government media release, Sunshine Coast international submarine cable construction begins, 9 February 2019.

209 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3.

210 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 7.

211 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 7; Mr Lau Saili, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 7.

212 Mr Lau Saili, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, pp 7-8.

> *in communication or a slowing then there is a backlog. That includes getting it from small businesses to the customer. From that perspective, good internet connection and other transfer technologies is definitely required.*[213]

Ms Starkey also highlighted the need for adequate data storage facilities to support the increased rate of downlink:

> *From a data storage perspective, we have to tap into stores globally, cloud based infrastructure as well as holding our own localised storage. The storage does get large fast, so there is going to need to be more investment into that in the future.*[214]

The committee notes that Queensland is home to Australia's first Teir III regional data centre, located in Toowoomba, which supports international and local business data storage needs.[215]

Committee comment

The committee considers that Queensland, in particular regional Queensland, offers multiple locations for ground stations. Throughout the inquiry, the committee heard that additional ground stations in Australia would provide for fasting downlinking of data from satellites, and ultimately increased benefits for end users in the application and commercialisation of that data. Additionally, the development of ground stations in Queensland would add to Australia's sovereign capabilities. The development of additional ground stations in regional Queensland must also be supported with the provision of better internet and telecommunication services in regional Queensland.

The committee also heard evidence that the development of ground stations (comprising the antenna and a nearby data processing centre) could promote the creation of nearby hubs of innovative technology, opening up a range of commercial opportunities. These hubs can act as incubators for businesses developing ways in which the data can be packaged and sold, for example through the design of algorithms and use of artificial intelligence. The committee heard that this is a significant area for job creation opportunities, particularly for regional Queensland. In order for Queensland to benefit from these opportunities, the committee recommends the Queensland Government investigate the development of additional ground stations in Queensland and ways in which to incentivise and strongly encourage businesses to process and analyse data downlinked from ground stations in Queensland.

Recommendation 3

The committee recommends the Queensland Government consider the findings of the Department of State Development, Manufacturing, Infrastructure and Planning feasibility study into the siting options available throughout Queensland to develop additional ground stations.

Recommendation 4

The committee recommends the Queensland Government consider the findings of the Department of State Development, Manufacturing, Infrastructure and Planning feasibility study into the siting options available throughout Queensland to develop satellite parks and to support the co-location and development of innovation hubs.

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213 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 21.

214 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 20.

215 Pulse Data Centre, available at https://www.pulsedc.com.au/, accessed 8 February 2019.

Recommendation 5

The committee recommends the Queensland Government continue to negotiate with the Federal Government on the expansion and upgrade of internet connectivity to and within Queensland to support the development of ground stations, satellite parks and innovation hubs.

Recommendation 6

The committee recommends the Queensland Government investigate approaches to incentivise and encourage businesses to be based in Queensland to process and analyse data downlinked from ground stations.

7.4 Earth Observation opportunities for Queensland

The committee heard that there is a 'natural cluster' of EO industry activity in Queensland, with a range of companies located across south-east and regional Queensland. Mr Kinne, DigitalGlobe, explained:

> *South-East Queensland from an industry point of view already has for one reason or another—historical perhaps—a natural cluster of remote-sensing companies that can leverage these technologies. They are based in Toowoomba, on the Darling Downs and around Brisbane. From my observation in the industry, there are more of those companies in South-East Queensland than there are concentrated in any other capital or any other state. From my observations, we have a natural cluster.*[216]

Earth Observation Australia similarly highlighted Queensland's existing industry capability in earth observation analytics, citing a number of international and national companies based in Queensland, and a growing group of SMEs:

> *In southeast Queensland, there are six international and five national headquarters for EO data collection and analysis including DigitalGlobe, Boeing, EOMAP, Data Farm Geospatial Intelligence and Geoimage; and a growing number of next generation small and medium-sized enterprises (SMEs) including Ozius Spatial, Proagrica (previously SST Software), Strategenics, Urban Circus and AgDNA. In addition, all of these groups have links to research and development at major universities.*
>
> *In regional Queensland there is a growing group of established medium sized EO data collection and analysis companies and a growing number of SMEs, including shemaps, DataFarming, Cibo, AIMS, CNC Project Management, Mangoesmapping and Station Innovation.*[217]

Additionally, the committee heard that Queensland has a distinct advantage due to its diverse economic and environmental conditions. Ms Starkey, Ozius, explained:

> *Operating your business in Queensland means earth observation solutions must cater for broadscale information through to fine-scale detail—hundreds of thousands of square kilometres to a few hundred metres; from the tropics to the deserts and pastoral plains to dense urban areas as well as sensitive marine and coastal environments. Queensland has all manner of industries operating across these varying landscapes.*[218]

The committee was informed that earth observation analytics does not require access to extensive physical infrastructure and can be carried out using high end personal computers with consistent broadband internet access. In Queensland, this has allowed the development of regionally specific

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216 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 32.

217 Earth Observation Australia, submission 6, p 6.

218 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 18.

industry to support EO analytics located close to production sites for agriculture, horticulture, aquaculture, mining and renewable energy production.[219]

> *Currently there are a number of EO analytics providers operating as small-medium enterprises located in regional centres across Queensland such as Toowoomba, Sunshine Coast, Gold Coast Townsville, Cairns, and Longreach. This is also reflected in the statewide distribution of geospatial analysis and EO analytics capabilities in local and state government regional offices.*[220]

Building earth observation activities and ecosystems will promote upstream applications in terms of developing industry-specific satellites and sensors. Professor Phinn from UQ told the committee:

> *… our focus on building earth observation analytics can create increased demand for upstream space capabilities. That could include looking at dedicated ground receiving stations here to help receive satellite imagery and process it more quickly and clearly, and developing dedicated satellite systems for specific industries that would then lead on to launch capability.*[221]

Similarly, Ms Starkey, Ozius, stated:

> *… we rely on external sources—as I mentioned, information from NASA, European Space Agency and commercial providers from France, China, America and South Korea. We have tapped into satellites from all over the world at the minute. With the announcement of the Australian Space Agency, it would be very exciting to start to lean on some domestic launched capabilities as well, but at the minute we rely on other data sources which is very interesting from the perspective that they are all outside of Australia.*[222]

There is momentum building in the volume of data that is available, which provides opportunities for companies in Queensland to innovate and find new ways of using that data. Ms Starkey told the committee that businesses need to leverage data to operate more efficiently and that this could lead to the creation of jobs in analytics or within the businesses themselves:

> *We are just about to hit a tidal wave of data that businesses can leverage. I think that growth and jobs can be established along many paths of that ecosystem. It can be established in the analytics space, where my business is, in that more businesses can look at different aspects of this data to solve different problems for Queensland businesses and there can be jobs in the actual business of analytics.*
>
> *There can be more growth and opportunities for existing companies and users to augment their business practices in order to consume the information that we are providing and make better decisions from that. At the minute that is a huge opportunity, but I think we need support for big business to embrace this technology and to see it as a viable solution.*[223]

Ms Starkey highlighted that for this technology to be more widely used, it would be beneficial for customers to have confidence that it will be accepted at a regulatory level (for example, as evidence of compliance with reporting conditions). This technology is also an opportunity for government and regulatory bodies to improve the way that they do business, for example, by remotely assessing what is happening on the ground and only sending people when and where it is required. [224]

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219 Professor Stuart Phinn, submission 10, p 9.

220 Professor Stuart Phinn, public hearing transcript, St Lucia, 19 October 2018, p 28.

221 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 28.

222 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, pp 19-20.

223 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 19.

224 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 19.

7.4.1 National Earth Observation Hub

The committee took evidence from Earth Observation Australia (EOA) and Professor Phinn from UQ who outlined the need to develop a National Earth Observation Hub for Earth Observation Analytics in Queensland given both the importance of EO and the existing critical mass and established industry, research and government linkages within Queensland.[225] EOA noted that:

> *Industry and government use of EO data, products and analytics requires fully operational EO data streams from satellite to desktop and users. The Hub would provide the only full combination of required sciences and engineering (for collection, advanced correction, biophysical modelling, large time series analysis, computational maths and statistics, AI and data delivery) in Australia, across research institutions, and government that have established national and international track records in developing and delivering operational solutions.*
>
> *As many private sector companies are founded by well-respected and well published researchers and scientists in their own right, the Hub provides a means for all of Australia's leading EO practitioners and technologies to come together to solve national and global challenges. This approach will enable research institutions to have access to the best minds as well as the best proven and applied analytics and technology in the private EO sector, and vice versa.*[226]

Professor Phinn told that committee that discussions on the Hub development has been in association with CSIRO with the view to develop the EO Hub in line with existing research centre, which allows companies to retain the intellectual property (IP) on products developed.

> *We would look at adopting an approach to intellectual property that would be similar to the Defence intelligence centre projects, where the companies would initially retain their IP and license it back to … the hub if they wanted to use it down the track. That way, small companies can come in and build on their ideas and go out whereas with other models, like in some of the older CRC models, they might potentially lose some control over the IP in that area. It is the timeliness and trying to make sure we can build the small to medium enterprise side of it but also engage with larger companies if they choose to as well.*[227]

The EOA recommendation that the Hub would operate physically from:

> *1. A set of shared offices, potentially in the Boggo Road, Ecosciences Building 3, where Hub staff would work with partner companies and research and government staff in a development, workshop and start-up office space (the proposed building will focus on science-industry partnerships)*
>
> *2. The offices would be connected to AARNET and have required high speed internet and security connections; and*
>
> *3. A receiving station and associated processing hardware facility for satellite image data acquisition from commercial providers.*[228]

The development of the Hub was argued to create multiple opportunities for economic growth and employment within many sectors and industries in Queensland and Australia.

> *The Australian earth observation community, along with multinational companies and multiple recent global market projections, does show that earth observation is a key niche area where Australia's space capability could be developed to offer the best use of our established investments and expertise. I highlight the Queensland Government's investments and expertise*

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225 Earth Observation Australia, submission 6 and Professor Stuart Phinn, submission 10.

226 Earth Observation Australia, submission 6, pp 3-4.

227 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 32.

228 Earth Observation Australia, submission 6, p 4.

in that area… If we build on those, that can maximise returns to the state and also to the nation.[229]

The department informed the committee:

- *The National Earth Observation Hub for Earth Observation Analytics proposal is strongly tied to a national consortium's SmartSat bid for a Federal Government Cooperative Research Centre (CRC) grant which has been recently shortlisted for further government consideration.*
- *The establishment of the hub would signal the state's national leadership of this part of the space sector, and boost Queensland's existing, nation leading commercial and R&D capabilities.*
- *DSDMIP and the DES continue to engage and support the Queensland proponents of the hub and SmartSat CRC bid and are actively monitoring its progress.*[230]

Committee comment

The committee notes that Queensland has well-developed research and industry capabilities in earth observation and analytics, and that is an area of the space supply chain in which there are significant job opportunities.

Further, the committee considers there to be merit in the proposal for the Earth Observation Analytics Hub as a way to create opportunities for employment in Queensland. To this end, the committee recommends the Queensland Government continue to support the Queensland proponents of the National Earth Observation Hub for Earth Observation Analytics as a way to create job opportunities in Queensland.

Recommendation 7

The committee recommends that the Queensland Government support the development of the National Earth Observation Hub for Earth Observation Analytics in Queensland.

7.5 Queensland's skilled workforce

Queensland is well-placed, due to its existing workforce capability, to secure a share of Australia's space opportunities.[231] There are a number of companies with a presence in Queensland that are actively involved in the space supply chain, including a range of start-ups and small to medium enterprises.[232] Additionally, the state has a highly skilled workforce in a variety of sectors relevant to the space supply chain, such as manufacturing, technology, mining, aviation and defence.[233] In order to develop and leverage Queensland's existing workforce capabilities into niche areas of the global space supply chain the department advised:

…it is the goal of the Queensland Government to not only assist industry with existing space capabilities to compete with a global space industry but to identify and introduce Queensland based businesses into the space sector for the first time and to help them develop the capability to do so.[234]

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229 Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 27.

230 DSDMIP, correspondence, 24 October 2018, p 8.

231 DSDMIP, submission 16, p 4.

232 DSDMIP, submission 16, p 9.

233 Mr James Minchinton, **s**ubmission 12, pp 8-9.

234 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 2.

There are a variety of companies involved in the space supply chain with a connection to Queensland. They range from global aerospace companies with a base in Queensland, such as Boeing Defence Australia, Airbus, Northrop Grumman and Raytheon, to start-up companies such as NEO Resource Atlas Pty Ltd (NEORA) and Ozius.[235] According to the Space Industry Association of Australia (SIAA), Queensland has considerable capability in the space sector with approximately 126 space-related organisations with a presence in Queensland.[236]

The committee was informed that Queensland companies have a growing role in the space industry, with 30 companies with a significance presence in Queensland, directly active in the space industry, or aerospace, supply chain (Appendix D).[237] This includes a number of companies that the committee heard from directly as part of the inquiry, such as:

- Hypersonix, which commercialised the hypersonic technology developed out of UQ over the past 30 years, including scramjet technology and the SPARTAN system.[238]
- Black Sky Aerospace, a provider of launch services, including launch vehicles, propulsion systems, telemetry and consultation. The company is based in Logan, Queensland. Black Sky Aerospace operates the only commercial sub-orbital launch site in Australia, located in Tarawera, north-west of Goondiwindi.[239]
- Gilmour Space Technologies, which designs and manufactures propulsion systems that deliver small low-cost satellites into space. Gilmour Space Technologies is based on the Gold Coast and recently raised $19 million in venture capital backed by CSIRO towards the launch of its first commercial hybrid rocket into space in 2020.[240]
- Products for Industry, an automation and robotics upgrade company serving the industrial sector out of Brisbane.[241]
- DigitalGlobe, a global company that owns and operates the highest resolution commercially available satellites and produces data for companies such as Google, Apple and Microsoft.[242]
- Boeing Defence Australia, which noted that its presence in Queensland is the largest outside of the United States and that its strong relationships with subject matter experts can assist to develop space projects in Queensland.[243]
- Ozius, which is an earth observation analytics company established and based in Brisbane. The vision of Ozius is to revolutionise the way that society measures, monitors and manages the environment by fusing earth observation data with environmental science and artificial intelligence to create new knowledge of the environment.[244]

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235 Neo Resources, submission 25, p 1; DSDMIP, submission 16, p 8; Ms Alisa Starkey, public briefing transcript, Brisbane, 1 February 2019, p 18.

236 Space Industry Association of Australia, submission 8, p 3.

237 DSDMIP, submission 16, p 8.

238 Professor Michael Smart, submission 13, p 3.

239 Black Sky Aerospace, submission 14, p 1.

240 DSDMIP, submission 16, p 9.

241 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 35.

242 Mr Peter Kinne, DigitalGlobe, public hearing transcript, Brisbane, 16 November 2018, p 30.

243 Boeing, submission 23, p 7.

244 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 18.

Throughout the inquiry, the committee heard of the collaborative efforts of companies involved in the space industry in Queensland.[245] Given the breadth of capability required along the space supply chain, there are opportunities for companies to work together and share ideas, technology and information.[246] Mr Nikolic, Black Sky Aerospace, described this as 'co-creation' and explained how his company works closely with other space-related companies to align their goals with the best interests of the industry.[247] Mr Gilmour, Gilmour Space Technologies, similarly commented on the positive nature of the space community:

> *…people are happy to share experiences and what went wrong. They are very encouraging and people are willing to help each other out. There are a lot of businesses sharing ideas and products and the community is very friendly. When you go to a space conference and you talk to people in the launch industry, they are all very friendly. They talk about some of the issues they have had and you all learn from each other.*[248]

Building partnerships is critical, both between space start-up companies and also between start-ups and multi-nationals that already well established in the industry. The committee heard that this will allow Queensland, and Australia, to play a more significant role in the space industry:

> *…the space economy is global and there are well-established multinationals who will be difficult to compete with… In many cases the best option, especially for start-up space industry companies in Queensland, will be to provide niche capabilities to the major companies within a supply chain.*[249]

Throughout the inquiry the committee heard evidence that Queensland has existing capabilities across a range of sectors relevant to the space supply chain, including:

- manufacturing and technology
- mining
- aviation and defence.

7.5.1 Queensland's manufacturing and technology expertise

Queensland companies already possess the manufacturing skills and technological expertise to develop space-ready technology. In particular, the committee heard that Queensland has existing capabilities in advanced manufacturing, 3D printing, high-tech materials, earth observation, remote asset management and robotics, a lot of which has been driven through the agriculture and mining sectors.[250]

Throughout the inquiry, the committee was provided with examples of products and technology that were developed in Queensland and have already been used in the space industry. Mr Gilmour, Gilmour Space Technologies, told the committee that almost all of his company's suborbital launch vehicle was built in Queensland and that the state has strong technology capability.[251] Similarly, Mr Nikolic, Black

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245 See, for example, Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 20; Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 20.

246 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 14.

247 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 20.

248 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 20.

249 Dr Andrew Dowse AO, Air Vice-Marshal (Retired), public hearing transcript, Brisbane, 1 February 2019, p 12.

250 Air-Vice Marshall (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 44.

251 Mr Adam Gilmour, Gilmour Space Technologies, public hearing transcript, Brisbane, 16 November 2018, p 14.

Sky Aerospace, outlined to the committee that his company's launch vehicle was primarily manufactured using local components and integrated locally at Logan.[252] The committee also heard that Black Sky Aerospace were working towards local manufacture of its propulsion system, which is currently manufactured in North America.[253]

The committee was also told about a range of virtual technology and software that has been developed out of the Boeing Research and Technology Centre and used for space-related purposes. Dr Armstrong, Senior Manager of the Centre, explained that Boeing had completed a first version of the 'Starline simulator' in virtual reality. Dr Armstrong explained the development of virtual simulators reduces the need for expensive physical simulators and also allows for up to date training for people on long-duration space missions:

> *You put the goggles on, you are inside the capsule, you can interact with the flight panel and you can perform a procedure like docking with the International Space Station.*[254]

Dr Armstrong also outlined how the Centre is producing software with potential application in space:

> *One of the areas that is applicable to space activities is that we have created a weather server and a whole simulator that will simulate the world in a variety of ways. If we look at the weather server, it looks historically at weather that has happened around the world on any given date; it is all archived—different altitudes, the oceans, the land, cloud cover et cetera. One of the applications potentially for it is for satellite prediction and usage. It can predict and in certain ways work out what cloud cover there may be and what the sampling rates may be for imaging to optimise satellite usage. That is another piece of software that we have developed locally and discussed in terms of its use for space.*[255]

In addition to the manufacturing and technology expertise that is already being used in the space industry, stakeholders commented that there is potential for the industry and government to connect with more Queensland companies to explain how products or technology they are already developing could be used in the space supply chain. The committee heard that there is a significant and varied market in the space supply chain, and it is not necessary 'to be a big piece in a big supply chain to have a very nice business'.[256] Mr Green, Products for Industry, explained:

> *There is not a technology that is not already being used across-the-board in Queensland that cannot be only mildly adapted to be immediately producing rocket components. It is not a huge outlay at all for industries to start getting involved. A lot of the time the problem is that the company just simply does not know that their technology can do that. There is obviously some education to be had.*[257]

Mr Nikolic, Black Sky Aerospace, explained the various components that are necessary for an aerospace vehicle and noted that many companies could already be manufacturing suitable products:

> *..there are the Ma and Pa nuts and bolts shops that do not know that they could sell a part that could be put into an aerospace vehicle. It is not just into the vehicle; there are the stands that we*

252 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 27.

253 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 27.

254 Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 54.

255 Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 54.

256 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 13.

257 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 36.

have to support the vehicle and there is other ground support equipment that is required. A lot of people and companies would not be aware that they might have a product that suits.[258]

Educating the community about the opportunities that exist in the space industry, and the variety of skills that could be relevant to the space supply chain, was also highlighted by Mr Minchinton:

It is likely the case that many Queensland enterprises aren't yet aware of the opportunities that exist for them in the space industry because many might consider that the space industry requires specialist expertise. However, it is the case that many of the everyday tasks of enterprises would also be beneficial to the space industry…

Manufacturers, precision engineering enterprises, transportation companies, fuel and chemical suppliers, resources companies, construction firms, telecommunication specialists and more could all play significant roles in any space industry but may need to be appraised of the new frontier on which their existing skills and expertise could be employed. Similarly service providers to all of these industries would be needed to support a move by these industries into a space industry.[259]

In addition to introducing new businesses to the opportunities that exist in the space supply chain, the committee heard there is also a need to facilitate connections between those already within the industry to further its development. Air Vice-Marshal (Retired) Neil Hart noted that this will become easier now that Australia has an established space agenda:

There are people who build the most advanced radars and sensors in the world here in Queensland, or artificial intelligence software and autonomy, but they are not connected to a satellite manufacturer or they are not connected to a rocket builder…

An important part of this is just creating that connection between all of these often fragmented and disparate small pieces which has been driven by the fact that we have not had a national space agenda and policy up until now. We have been a net user of space rather than talking about creating an industry.[260]

The committee was also made aware of the need to educate companies and individuals in the space industry and those wanting to become involved in the industry, about the support that is available from research organisations and government. For example, Dr Williams, CSIRO, explained to the committee that one of the difficulties faced by small companies in particular is that they were unaware of the assistance they could seek from organisations like CSIRO:

There are a whole range of technologies where CSIRO has parallel skills and where our ambition with industry is to say to them, 'Do not start from scratch. Come and have a look at what we can do to help you, where you can pick up from what we have and then go off and do your own thing…'[261]

To address this issue, CSIRO started to hold regular meetings with 30 to 40 small space companies to explain how the organisation can assist them as they progress through the industry:

You do not realise how difficult it is for SMEs to find out what is available in a country from a nationally funded organisation, so the first challenge was just explaining the range of capability we have. We are now moving into helping individual companies address the problems they need to solve as they go forward. We are not trying to interfere and we are not trying to upstage them;

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258 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 28.

259 Mr James Minchinton, submission 12, p 5.

260 Air Vice-Marshall (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 50.

261 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 13.

it is really a matter of trying to say, 'Well, you don't need to do that because we can do it. We have people skilled in data analytics.'[262]

Ms Johnston, DSDMIP, explained to the committee the variety of state government funding opportunities for businesses seeking to be involved in the space industry:

The department also offers numerous services, funds and grants to drive the growth of Queensland's space industry. The government's flagship suite of funds is the $650 million Advance Queensland program, which includes the $105 million Industry Attraction Fund, which encourages innovative companies to Queensland and local companies to expand; the $80 million Business Development Fund, which assists with the development of high-value, knowledge based skilled jobs by providing early stage co-investment of up to $2.5 million; and the Ignite Ideas Fund, which provides seed capital for Queensland start-ups and SMEs so they can commercialise market-ready innovative ideas.

The Minister for State Development, Manufacturing, Infrastructure and Planning will also soon launch the $2 million Defence and Aerospace Industry Development Fund to provide financial support to Queensland SMEs to help them access international events and attain acquired accreditation and certification within the defence and aerospace sector. [263]

7.5.2 Mining

The committee heard that much of the manufacturing and technology expertise in Queensland has been driven by the mining sector, particularly in the areas of autonomous systems, remote asset management, artificial intelligence and robotics.[264] Ms O'Sullivan, Principal Research Fellow at UQ's Sustainable Minerals Institute, stated:

Some of the largest mining companies are owned and operated in Australia. We have deep expertise in metals mining, oil and gas extraction, safety, exploration and remote sensing applications, airborne geophysics, environment, modelling, reporting and governance of the mining sector.[265]

Stakeholders commented that Queensland's mining expertise provides a unique opportunity for the state to differentiate itself in the space sector.[266] Such expertise is relevant to space exploration, for example in developing or testing equipment designed for space, and potentially space mining (in-situ mining on the Moon/Mars or asteroid mining).[267] Mr Minchinton explained:

There is a good chance that at least part of the commercial exploitation of the space industry will be driven by a need for mineral resources. Indeed, enterprises are already in existence which seek to mine asteroids. Queensland could seek to leverage its expertise and existing competitive advantages in the mining sector and mining services sector to help to develop this aspect of the space industry.[268]

The department advised that Queensland's 'remote asset management and remote sensing technologies present world-leading competitive advantages in the development of technologies,

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262 Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 13.

263 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3.

264 Air Vice-Marshal (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 44; DSDMIP, submission 16, pp 9-10,

265 Ms Rhonda O'Sullivan, submission 9, p 2.

266 Ms Rhonda O'Sullivan, submission 9, pp 3, 9.

267 Ms Rhonda O'Sullivan, submission 9, p 5.

268 Mr James Minchinton, submission 12, p 5.

products and services targeted at the extraction of valuable geological materials in space'.[269] Ms Melroy, Director of Space Technology and Policy, Nova Systems, stated:

> *Australia's autonomous mining and advanced manufacturing technologies could be successfully applied to ISRU [in-situ resource utilisation] and to support economically viable mining for rare earth metals which are abundant on the Moon. Importantly, no other country is looking to own this technology space, so efforts now could result in a technological and economic leadership role for Australia.*[270]

However, Ms Melroy noted that although remote asset management and autonomous mining are developed capabilities in Australia, adapting them to space requires additional technical and policy work. Ms Melroy advocated for an 'Institute for Remote Asset Management, Manufacturing and Maintenance in Extreme Environments' which would bring together existing capabilities with the research and development required to transition the technologies to the space domain.[271]

> *Queensland could play a critical role in this institute, serving as the hub for robotics, trusted autonomy, and advanced field manufacturing. The goal is for Australia to become the provider of remote asset management technologies for future international lunar exploration, which is expected to develop over the next ten years.*[272]

Ms Melroy submitted that Queensland has many existing organisations with capabilities that can contribute to a national effort, including:

- *QUT Centre for Robotic Vision*
- *Autonomous Port Operations*
- *Advanced Robotic Manufacturing*
- *Defence CRC – Trusted Autonomous Systems*
- *CSIRO Queensland Centre for Advanced Technologies – Sensors, Communication, Underground Autonomous Mining*
- *Boeing Centre for Autonomous Vehicles*[273]

Mr Green, Products for Industry, similarly commented on the opportunity to draw on Queensland's mining expertise to develop 'space ready' technology:

> *Even if it is a fairly light piece of mining equipment, most technology that is developed for the planet is not suitable for space. Even if it is light enough, there are still joint systems, engineering concerns, degassing systems, power systems—all of these things that come into play that are not suitable for either low-gravity or zero-atmosphere situations. There is a huge opportunity for Australia, if we have the technology sitting in our backyard that we are currently using, to work out ways that we can get that to become space compliant. Once we go down that road, we can do a lot of other systems, whether that be testing satellites and other systems, for being ready for space.*[274]

The committee was told that a potential by-product of developing technology and extraction methods for space exploration is that such research and development could uncover more effective ways of

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269 DSDMIP, submission 16, p 9.

270 Ms Pam Melroy, submission 24, p 2.

271 Ms Pam Melroy, submission 24, p 3.

272 Ms Pam Melroy, submission 24, p 1.

273 Ms Pam Melroy, submission 24, p 4.

274 Mr Nick Green, Products for Industry, public hearing transcript, St Lucia, 19 October 2018, p 40.

extracting current resources and extending the life of mines in Queensland.[275] Further, due to the similarities of the mining and space industries, the committee heard that there could be a 'cross-over' in job opportunities between these industries. Ms Melroy explained:

> *Another major outcome from technology cross-flow is the potential to smooth out the cyclical nature of both the space and resources industry to allow cross-flow of people when one industry experiences a down-turn. A great example of this is that when the Space Shuttle program ended many engineers in Houston left the space industry for the oil and gas sector. When the oil and gas sector experienced historically low prices and the space industry was picking up, there was a migration back into space.*[276]

Mr Nikolic, Black Sky Aerospace, also commented on the cross-over between these industries and provided an example of where Queensland's mining expertise has been used in the space industry:

> *Our robotics guy in Black Sky Aerospace is involved in a lot of mining aspects. His claim to fame is that he developed part of the science lab that is on Curiosity, which is sitting on Mars right now. It was designed to take soil samples from Mars, so there is a big crossover there with mining. Again, because of the harsh natures, the testing for robotics and putting things into remote environments, there is a massive crossover.*[277]

Related to Queensland's experience in the mining sector, the committee heard that Queensland's abundant resources are useful to generate electricity to powering space industry facilities and that the state could leverage its energy expertise to produce fuels for launch vehicles.[278] Additionally, Boeing submitted that many Queensland industries already utilise specialised materials (including hazardous chemicals and explosives) and this could support the unique requirements of the space supply chain.[279]

7.5.3 Aviation and defence in Queensland

Queensland has a long heritage in the aviation industry and is considered to have a 'very robust aerospace sector.'[280] The committee heard that there are a large number of aerospace primes and SMEs in Queensland that are engaged in space activities or interested in becoming engaged in space activities.[281] According to the department, Queensland aircraft manufacturing and repair businesses generated approximately $1.2 billion in revenue in 2015-16 and provide 4,200 jobs across more than 300 enterprises.[282] The space industry offers opportunities for these, and other, skilled workers to apply their expertise in an emerging sector.

> *Space is a logical progression for Queensland's nation-leading aerospace industry. The state has a highly skilled workforce and a strong research base in both the civil and military sectors. This expertise and skill will be adaptable and transferrable to an emerging space sector.*[283]

The committee heard that there is a strong connection between the regulation of aviation and space activities and that Queensland's expertise will be beneficial to numerous aspects of the space supply chain. Queensland already has expertise in air and space law, and as more companies become engaged with space activities, there will be an increased need for legal and other professional services to assist

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275 Ms Rhonda O'Sullivan, UQ, public hearing transcript, St Lucia, 19 October 2018, p 22.

276 Ms Pam Melroy, submission 24, p 4.

277 Mr Blake Nikolic, Black Sky Aerospace, public hearing transcript, Brisbane, 16 November 2018, p 22.

278 Mr James Minchinton, submission 12, pp 3, 6.

279 Boeing, submission 23, p 6.

280 Air Vice Marshall (Retired) Neil Hart, public hearing transcript, St Lucia, 19 October 2018, p 43; Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 39.

281 Ms Denise Johnston, DSDMIP, public hearing transcript, St Lucia, 19 October 2018, p 47.

282 DSDMIP, submission 16, p 8.

283 DSDMIP, submission 16, p 2.

these companies in navigating the associated legal and regulatory framework.[284] This is particularly relevant given the establishment of the Australian Space Agency and recent amendments to the legislative framework through the *Space Activities Amendment (Launches and Returns) Act 2018 (Cth).*[285]

Another area where Queensland's aviation experience is relevant to the space industry is space traffic management. Mr Blake, IALPG, explained that due to the increasing number of small satellites going up into space, space debris and potential asteroid mining in the future, there will be a growing demand for some sort of regulation of traffic management in space. Mr Blake considered that Queensland has a particular advantage in this respect:

> *The experience in respect of air traffic management, such as in the Brisbane centre which provides air traffic services for a huge portion of the earth's surface, would be valuable in respect of the development of an increasingly critical space traffic management regime.*[286]

Further, Queensland has a competitive advantage in the space industry due to its significant connections with the military and Defence. Australia's largest defence airbase is located at Amberley, south-west of Ipswich and Queensland-based Air Force personnel are skilled in Geographic Information Systems (GIS) and electronics engineering.[287] The committee heard that there are also many companies based in Queensland that have contracts with national and international defence forces. These companies are 'accustomed to producing products and services of the highest standard and working in a tightly regulated environment', a requirement for production for the space industry.[288]

The committee heard that ex-military and ex-Defence personnel with specialised expertise in GIS, remote sensing, image analysis and artificial intelligence would contribute valuable skills to the space industry.[289] However, there was no clearly established pathway for these personnel into relevant public/private sector roles where this unique expertise could be utilised.[290] In regard to supporting these personnel into relevant careers post-service, the Department of Employment, Small Business and Training advised that 'under the VET investment plan, Queensland's ex-service personnel and veterans are supported to participate in a range of programs and initiatives that provide reskilling opportunities targeted at employment.'[291] Further, ex-service personnel and veterans have been added as a key target group under the government's Skilling Queenslanders for Work Initiative and are able to access concessional subsidies towards the cost of training.[292]

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284 Mr Joseph Wheeler, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 38; Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 41.

285 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 42.

286 Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 39.

287 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 3; Submission 16, p 8.

288 DSDMIP, submission 16, p 8.

289 See public briefing transcript, Brisbane, 15 October 2018, pp 8, 13.

290 Mr Steve Jacoby, DNRME, public briefing transcript, Brisbane, 15 October 2018, p 13; Professor Stuart Phinn, UQ, public hearing transcript, St Lucia, 19 October 2018, p 33.

291 Mr Steve Koch, Department of Employment, Small Business and Training, public briefing transcript, Brisbane, 12 November 2018, p 3.

292 Mr Steve Koch, Department of Employment, Small Business and Training, public briefing transcript, Brisbane, 12 November 2018, pp 3-4.

The Department of Defence acknowledged there is an opportunity to provide more pathways for ex-military personnel into the space industry. Air Marshal McDonald explained it might involve making people aware of pathways into smaller organisations within the industry:

> *…people gravitate out of Defence and more commonly go to the larger organisations. Maybe they are attracted financially or perhaps they just do not know that others exist. Maybe that is one avenue—making them aware that other opportunities exist in smaller industry.*[293]

Committee comment

The committee notes the presence of a significant number of companies in Queensland that are already actively involved in the space supply chain. The committee considers that there are more companies and individuals with the skills, products and services which could become part of the space supply chain. The committee encourages the Queensland Government to promote access to the opportunities offered by the space industry, including introducing and helping connect new businesses to the sector.

To this end, the committee recommends that the Queensland Government develop a range of targeted promotional activities and resources detailing the opportunities for Queensland business in the space supply chain.

Additionally, the committee recommends that the department promotes awareness of available funds and assistance (such as that provided through Advance Queensland, the Defence Innovation Hub and CSIRO) currently offered to businesses seeking to participate in the space supply chain.

The committee acknowledges Queensland's skilled workforce (for example, in areas of manufacturing and technology, mining, aviation and defence) and recommends the department consider mechanisms to encourage local companies to offer internships to individuals, to provide pathways into the space industry.

Recommendation 8

The committee recommends the Department of State Development, Manufacturing, Infrastructure and Planning develop a range of targeted promotional activities and resources detailing the opportunities for Queensland businesses in the space supply chain, including information and networking events.

Recommendation 9

The committee recommends the Queensland Government develop strong links between the Queensland space industry and Advance Queensland, the Defence Innovation Hub and CSIRO to facilitate participation in the space supply chain.

Recommendation 10

The committee recommends the Queensland Government assist Queensland based space companies to offer internships to provide career pathways into the space industry.

[293] Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 9.

The committee recognises that the space industry requires a skilled workforce and considers Queensland's capabilities in the areas of manufacturing, technology, mining, aviation and defence will be advantageous in this regard. The committee notes the synergies between these areas and the space industry, and the potential to transfer skills and expertise to the space sector.

In particular, the committee acknowledges the close relationship between the space industry and defence. The committee heard throughout the inquiry about the importance of sovereign capability and the significant presence of the Department of Defence in Queensland.

Further, the committee heard that Defence personnel possess unique expertise in geographic information systems, remote sensing, image analysis and artificial intelligence and the committee considers such expertise would add significant value to a space industry in Queensland. The committee considers there should be formal structures in place to facilitate pathways between ex-Defence personnel and relevant roles in the space sector.

Recommendation 11

The committee recommends the Queensland Space Industry Reference Group examine pathways for ex-Defence personnel to transition to employment in the Queensland space industry.

7.6 Queensland's research capabilities

Queensland has significant research capabilities that underpin its skilled workforce. The state has access to world class universities and research centres that already support the space supply chain and are enthusiastic to see the space industry develop.[294] Ms Johnston from the department explained:

> *Research is the bedrock of a high-tech sector like space and Queensland is blessed with some of the nation's leading space related research institutions and academics as the state's four major universities are heavily invested in space research and development and most notably adopt a collaborative, rather than competitive, approach to developing our space knowledge and expertise.*[295]

During the inquiry the committee was made aware of the research activity being undertaken at Queensland's universities and research centres across a variety of areas relevant to the space supply chain. These include, for example, hypersonics, autonomous systems, advanced composite materials/manufacturing, robotics, earth observation, virtual technology, software development, solid fuel rockets and exoplanet exploration.[296] Professor Schubel, University of Southern Queensland, stated:

> *Queensland can confidently say that they are national and world leading in these topic areas, and therefore stand the highest probability of growing strength in these key areas resulting in the creation of spinout companies contributing to the Space sector supply chain.*[297]

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294 Boeing, submission 23, p 6. See also DSDMIP, submission 16, pp 10-11, which sets out in detail the expertise of UQ, QUT, University of Southern Queensland and Griffith University with respect to the space industry.

295 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 3.

296 Professor Peter Schubel, submission 18, p 1; Earth Observation Australia, submissions 6; Professor Stuart Phinn, submission 10; Professor Michael Smart, submission 13; public hearing transcript, Brisbane, 16 November 2018, pp 44-50.

297 Professor Peter Schubel, submission 18, p 1.

The Committee with senior UQ academics and stakeholders at the public hearing, University of Queensland, St Lucia, 19 October 2018.

The strong relationship between Queensland's research institutions and industry was raised as a significant advantage for Queensland in regard to its role in an Australian space industry. Dr Dowse AO, Air Vice-Marshal (Retired), Director of Defence Research and Engagement at Edith Cowan University stated:

> *I think one of the areas where it is possible to compete is by using the fantastic expertise that you have, particularly at the University of Queensland, QUT and other universities, whereby you can use the relationships that you have with local industry and also those big companies that you have within the state such as Boeing and grow those capabilities, get those good ideas.*
>
> *I really think that you look at where that core expertise is within your universities and your small to medium enterprises and try to incentivise those to grow and become big companies and revenue-producing ventures.*[298]

[298] Dr Andrew Dowse AO, Air Vice-Marshal (Retired), Edith Cowan University, public hearing transcript, Brisbane, 1 February 2019, p 16.

The committee was also provided with examples of the strong collaboration between research institutions and industry, and was told of particular instances where Queensland's research capabilities have been commercialised and are already contributing to the space supply chain. For example, UQ state they are world leading in scramjet technology and beat NASA to the first flight test of a scramjet with 'a fraction of the research budget'.[299] The SPARTAN reusable launch system, which uses scramjet technology, was developed out of UQ and is being commercialised by Queensland start-up company Hypersonix.[300] Hypersonix continues to works with other SMEs and with the Centre for Hypersonics at UQ on its reusable launch system, contributing to the local space industry.[301]

The committee heard that there is an opportunity to leverage Queensland's expertise and grow a research hub, with associated jobs. Dr Jahn, Deputy Director, Centre for Hypersonics explained:

> *Leveraging the already established critical mass of expertise provides an opportunity [to] grow a Queensland based research hub, with associated jobs, for advanced space transportation and re-entry systems. This would provide research services, new technologies, and innovation to the national and international space industries.*[302]

As discussed above, the committee was told that Queensland has significant research capabilities in earth observation and that the state is emerging as a major national hub for earth observation application development.[303] Queensland's universities 'are recognised nationally and internationally as leaders in the analytic development and application of EO data' and much of Queensland's work in this area is driving national capability.[304]

Queensland also has a niche advantage in the field of robotics and computer vision. The state is home to the Australian Centre for Robotic Vision, an Australian Research Council Centre of Excellence located at Queensland University of Technology in Brisbane. The Australian Centre for Robotic Vision is the largest collection of individuals with combined computer vision and robotics expertise in the world.[305]

Dr Keay, Chief Operating Officer of the Centre, stated:

> *Brisbane is, in some respects, the robotics capital of Australia. For a number of reasons we have ended up delivering a cluster of activity, both here at QUT and also at CSIRO Data 61's facility at Queensland Centre for Advanced Technologies (QCAT) at Pullenvale which means that we have the largest number of robotics researchers in any one given space in Australia. We have these unique advantages. We think there are a lot of opportunities in space for robotics and we would like to see that those are followed through.*[306]

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299 Professor Michael Smart, submission 13, p 3.

300 Professor Michael Smart, submission, p 1.

301 Professor Michael Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 1.

302 Dr Ingo Jahn, submission 22, p 2.

303 Professor Stuart Phinn, submission 10, p3.

304 Earth Observation Australia, submission 6, p 6.

305 Dr Sue Keay, Australian Centre for Robotic Vision, public hearing transcript, Brisbane, 16 November 2018, p 45.

306 Dr Sue Keay, Australian Centre for Robotic Vision, public hearing transcript, Brisbane, 16 November 2018, p 45.

Committee Chair, Chris Whiting MP with Professor Michael Milford at the Australian Centre for Robotic Vision, QUT, 16 November 2018

The Boeing Research and Technology Centre is also located in Queensland, with sites at UQ and Brisbane Airport. Boeing's research focuses on autonomous aircraft, modelling and simulation, and software development for remote testing.[307] Dr Armstrong, Senior Manager of the Centre gave an example of software that has been developed at the Centre and already utilised in the global space industry:

> *If you think about Skype and then you put it on steroids and imagine a package that lets people chat to people, send videos, send masses of data and have 45 people or so doing that at the same time, that is software we have developed here locally in Queensland, and it has already been used in satellite launches in the US. It enables support crews for launch to not all have to travel to Florida; they can be stationed anywhere in the world and be part of that launch and verification as that is going through. That is a locally developed piece of software.*[308]

[307] Dr Jason Armstrong, Boeing, public hearing transcript, St Lucia, 19 October 2018, p 53-54.

[308] Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 54.

The Australian Space Agency stated that endeavours like the Australian Centre for Robotic Vision and Boeing Research and Technology Centre contribute strongly towards to the building of Australia's knowledge base, fuel innovation, open up potential commercial opportunities, and may result in spill over effects for the broader economy.[309]

Another research organisation with a significant presence is Queensland is CSIRO. CSIRO works closely with Queensland's universities and industry on a variety of space-related activities, including earth observation analytics and applications, and space engineering and technologies.[310] For example, CSIRO's QCAT, located at Pullenvale, is Australia's largest integrated research and development precinct for the resources and associated advanced technology industries. QCAT draws together research and development providers and industry collaborators in fields such as robotics and autonomous systems, advanced aeronautical engineering and smart mining.[311]

Also located within Queensland are the:

- Defence Cooperative Research Centre for Trusted Autonomous Systems, a national centre for the development of drone and robotics technology for the Australian Defence Force.
- Terrestrial Ecosystem Research Network (TERN), based at UQ, which recently collaborated with NASA to study global climate.
- Centre for Advanced Materials Processing and Manufacturing (AMPAM), based at UQ, which has significant expertise in materials engineering and manufacturing activities.
- X3 expansion tube facility, based at UQ, which is capable of studying superorbital gas dynamic flows (i.e. the properties and behaviour of fuels in space propulsion systems).
- Institute for Future Environments, based at QUT, which is developing new technologies and methods for collecting and analysing big data through its IntelliSensing program.
- Institute for Advanced Engineering and Space Sciences, based at USQ, which has nationally leading applied research and commercial work in composites, hypersonics, robotic vision in uncontrolled environments and astronomy.
- Mount Kent Observatory, Queensland's only professional research observatory.
- Shared Skies Partnership with the University of Louisville in Kentucky, USA, operating out of USQ, which allows for remote access to telescopes around the world for live astronomical viewing.
- Institute for Integrated and Intelligent Systems, based at Griffith University, which specialises in artificial intelligence, computer image processing and robotics.[312]

In addition to housing numerous research and development centres, Queensland produces a large number of PhD, postgraduate and undergraduate students in sectors relevant to the space industry. However, the committee heard from various stakeholders that it can be a challenge to retain these students in Queensland post-graduation due to lack of job opportunities.[313] Professor Smart, Director of the Centre for Hypersonics at UQ, stated:

> *In our Centre for Hypersonics we have graduated more than 130 PhD students, and they are all over the world in different places doing very exciting things. We would love to bring them back and bring back what they have learned as well. They are out there doing really exciting things*

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309 Australian Space Agency, submission 21, p 7.

310 CSIRO, submission 5, p 5.

311 CSIRO, submission 5, p 5; See also Queensland Centre for Advanced Technologies website, available at: http://www.cat.csiro.au/

312 DSDMIP, submission 16, pp 10-11.

313 Public hearing transcript, St Lucia, 19 October 2018, p 27, 32-33, 45-46.

and we would like to take advantage of that and give them opportunities back here in Queensland.[314]

Dr Jahn, Deputy Director of the Centre for Hypersonics provided some further detail on the types of opportunities these graduates have pursued overseas and how a space industry in Queensland could assist in retaining talent:

For example the highly successful US funded Rocket Lab company in New Zealand, who successfully launched to orbit in mid 2018, employs a large number of our graduates. While it is great to see that many of our graduates have taken up roles with NASA, JAXA (Japanese Space Agency), DLR (German Aerospace Agency), and Rocket Lab this is also a clear indicator of the ongoing talent drain from the STEM sector within Australia. The same trend is reflected for Undergraduate students studying Mechanical & Aerospace Engineering, with many of the best students seeking opportunities for further studies and jobs abroad, so that they can work for the space industry. A Queensland based space industries would allow much of this talent to be retained and support the Australian economy and encourage more students into STEM, as there will finally be job prospects in Queensland.[315]

Dr Keay, Australian Centre for Robotic Vision, found similar patterns in the field of robotic vision, and told the committee that many of the Centre's talented graduates move overseas because there is a lack of local career opportunities.[316] Professor Milford, School of Electrical Engineering and Computer Science, QUT, explained further:

…some of them will come back if we create the right opportunities. In a way the bigger problem is not those few superstars but it is that pack of highly motivated graduates, both undergraduates and PhDs, who get out and look around for opportunities. They are not just looking for money. A small number of people are motivated very much by monetary opportunities overseas, but most of them want to have an impact, they want to do something interesting and they want to feel like they will have some chance of changing the world, of leaving some sort of stamp that leaves it in a better place. Their perception, as we have noted, at the moment—and given their short time frame; these people are impatient—is that that place is generally overseas.[317]

314 Professor Smart, UQ, public hearing transcript, St Lucia, 19 October 2018, p 7.

315 Dr Ingo Jahn, submission 22, p 2.

316 Dr Sue Keay, Australian Centre for Robotic Vision, public hearing transcript, Brisbane, 16 November 2018, p 46.

317 Professor Michael Milford, QUT, public hearing transcript, Brisbane, 16 November 2018, pp 46-47.

Committee Chair, Chris Whiting MP and Committee Member Jess Pugh MP with Dr Sue Keay at the Australian Centre for Robotic Vision, QUT, 16 November 2018

Products for Industry also highlighted the importance of attracting talent back to Australia in its submission, and drew on recent research from the Australian Academy of Science:

> *Many talented Australians have moved overseas to be involved in or lead space-based education, research and industrial programs. The inevitable growth in opportunities in a maturing Australian space industry will provide incentives for the return of expatriates, with associated knowledge transfer. In this way, Australia has the opportunity to turn an 'education brain drain' into an innovation diaspora.*[318]

Committee comment

The committee considers Queensland's universities produce highly skilled professionals and that Queensland has a significant amount of scientific and technical talent.

The committee notes that many of Queensland's students leave the state after graduation due to lack of career opportunities in Australia. The committee agrees with stakeholders that a more established space industry in Australia would provide local career opportunities for talented graduates, and potentially an incentive for former graduates to return to Queensland, build on the skills and expertise they developed overseas and create new successful Queensland companies.

Throughout its inquiry, the committee heard that there are already a significant number of companies that are active in the space industry in Australia and considers that more needs to be done to connect Queensland students with these companies to pursue opportunities. To this end, the committee recommends the department hold events in collaboration with Queensland's universities to connect science, technology, engineering and mathematics (STEM) graduates with Australian space companies,

318 Products for Industry, submission 7, p 5 and Australian Academy of Science, A vision for space science and technology in Australia, September 2017, p 14.

and facilitate pathways to local career opportunities in the space supply chain. The committee considers this will be increasingly important as the space industry develops in Queensland.

Recommendation 12

The committee recommends the Department of State Development, Manufacturing, Infrastructure and Planning hold events in collaboration with Queensland's universities to connect STEM graduates and students with Australian space companies and facilitate pathways to local career opportunities in the space supply chain.

7.7 STEM education in Queensland

Queensland's education system is well-positioned to help transform Australia's space industry and capitalise on emerging opportunities due to its emphasis on science, technology, engineering and mathematics (STEM). [319] The committee heard that:

> *For the Australian space industry to be successful… we need to inspire the next generation so that they have the skills that are there and, importantly, understand where we are going.*[320]

Air Marshal McDonald, Department of Defence, acknowledged Queensland's focus on STEM and highlighted the importance of maintaining this focus to get the most out of a space industry:

> *I would say that the starting point is mathematics and science at school. I believe Queensland is one of the few states that still makes it mandatory to take mathematics through years 11 and 12, and I applaud you for that. Other states have not necessarily done so. I think that is a deficit that this country must address if we are truly focused on getting into high technology or remaining in that space and particularly for the subject we are talking about today it is absolutely critical.*
>
> *If you make mathematics or other subjects optional, you will choose the easiest path forward, but easy is not what you need in space. You need to do the complex. That is the starting point. Space is a whole-of-nation endeavour if we wish to make it substantial.*[321]

More broadly, Air Marshal McDonald noted it is important to encourage and celebrate 'those people who wish to take an academic career and wish to contribute in such things as science, engineering and space in the future.'[322]

During the inquiry, the department provided the committee with a summary of some of the government's policies and programs relevant to the space sector, including the STEM strategy, Advancing Education plan, #codingcounts, STEM hub and Aerospace Gateway to Industry Schools program.[323]

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319 Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, p 1.

320 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 4.

321 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 3.

322 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 5.

323 DSDMIP, submission 16, pp 11-12. See also Queensland Government, Science Technology, Engineering and Mathematics, available at: www.education.qld.gov.au/curriculum/school-curriculum/stem

Ms Rosengrave, Department of Education, outlined three particular aspects of the STEM strategy that were relevant to the space industry:

> *…building partnerships with industries to ensure our students are connected to cutting-edge technologies and applications of STEM learning and have the knowledge of current and emerging career opportunities; encouraging girls in STEM and ensuring they are connected to female role models and choose to pursue STEM learning and career pathways; and raising awareness of the opportunities and the demands of a growing space industry in Australia.*[324]

The committee also heard from the Australian Space Agency and other stakeholders about the importance of education and its relevance to the space industry. The Agency noted that Queensland's education initiatives 'support the broader national initiative to increase STEM participation and performance, critical to the growth of Australia's economy.'[325] Dr Williams, CSIRO, also commented on the importance of education in the 'digital wave':

> *We are in the digital wave. We have to ensure that Australia gets the right skills into the system and the education system out of it and that we support the establishment of the right infrastructure to allow a digital world to emerge.*[326]

Mr Murfett, Australian Space Agency, noted the importance of involving school-aged children in technology early and keeping them engaged, including providing them with an idea of what STEM-related jobs look like:

> *In 10 to 15 years' time, regardless of the career, it is going to need some form of technology. People are going to need to know how to use a computer. They are going to need to know how to code. Those base skills are important. Starting early is one of the lessons that has come out internationally.*
>
> *It is about how you get involved and how you keep the engagement….The thing you want to do with STEM is have that vision about what the jobs look like so that people can work towards that particular outcome. Not everyone will go into that particular career, but if we can get the base skills I think that is an important part of the journey.*[327]

The committee heard from various stakeholders about space's ability to 'inspire the next generation' and the advantages this has for mobilising students into STEM subjects, and later STEM-careers.[328] Professor Milford, QUT, stated that space 'is one of the very few topics that can universally captivate, motivate and mobilise an entire population.'[329] Ms Melroy, Nova Systems, noted in particular how Australia's participation in lunar exploration could operate as inspiration for students to study in STEM fields.[330] Space exploration as a form of motivation was also mentioned by Mr Blake, IALPG, who explained to the committee how a Space Prize or similar space-related challenge could inspire the population, energise the local space industry and attract positive attention, innovation, energy and investment to Queensland.[331]

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[324] Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, p 1.

[325] Australian Space Agency, submission 21, p 7.

[326] Dr David Williams, CSIRO, public hearing transcript, St Lucia, 19 October 2018, p 18.

[327] Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 8.

[328] See, for example, Professor Michael Milford, QUT, public hearing transcript, Brisbane, 16 November 2018, p 45; Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 58.

[329] Professor Michael Milford, QUT, public hearing transcript, Brisbane, 16 November 2018, p 45.

[330] Ms Pam Melroy, submission 24, p 2.

[331] Mr Duncan Blake, IALPG, public hearing transcript, Brisbane, 16 November 2018, p 39.

The Australian Space Agency explained that part of its role was to tell 'the story of space' to inspire the next generation to be involved in the industry, or at least obtain the relevant STEM workforce skills:

> *One of the roles of the agency is about telling the story about the implications of space, what Australia can do and help that inspirational piece so we can inspire the next generation to either be involved with space or at least get the workforce skills in science, technology, engineering and mathematics. Even if they do not continue in space and they go into other fields, those skills are going to be needed regardless of what job they have 10 to 15 years down the track*.[332]

Industry also recognises the benefits of a STEM-educated population, not only to flow into STEM related jobs, but because future society will be based on technology.[333] For example, Dr Armstrong, Senior Manager, Boeing Research and Technology Centre, stated:

> *We need to do everything we can to get more students into STEM… I think one of the nice things about space as an area is that it is one of the more motivating fields to talk to kids about to get them interested in. They may not end up doing space, but it gets them interested in autonomous systems or computer programming or the engineering skills that we need to be a technology based society in the coming decades. I think space plays an important role in that technology development of our local area.*[334]

Air Marshal McDonald, Chief of Joint Capabilities, Department of Defence, commented that having a STEM-educated population can attract industry to Queensland and that it is important to retain a focus on mathematics:

> *I may be extrapolating here, but I would say to you that the reason Boeing has headquartered in Brisbane may well and truly be a direct reflection of availability of specific skills being in engineering, mathematics and science. I do not think it was by accident that Boeing decided to place a significant amount of investment in Brisbane. I would say that by keeping mathematics as a mandatory subject you remain in a box seat.*[335]

The committee heard that Queensland students are already achieving excellence in STEM-related fields. For example, Merrimac State High School students were presented with awards for coding at the World Robot Summit in Tokyo and Corinda State High School was the 2016 runner-up at the annual NASA International Space Settlement Design Competition.[336] The committee also heard that more Queensland schools are systematically planning for STEM improvements and are connecting with industry, university and community partners.[337] An example of this is through 'STEM champions', who are practising teachers, based at each of the seven Queensland school regional offices, and who develop industry partnerships and build greater capacity for young people in the STEM fields, including by sharing best practice across different schools.[338]

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332 Mr Anthony Murfett, Australian Space Agency, public hearing transcript, Brisbane, 16 November 2018, p 3.

333 See, for example Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 58; Dr David Williams, CSRIO, public hearing transcript, St Lucia, 19 October 2018, p 18.

334 Dr Jason Armstrong, Boeing Research and Technology Centre, public hearing transcript, St Lucia, 19 October 2018, p 58.

335 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 5.

336 Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, p 2.

337 Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, p 2.

338 Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, pp 4-6.

However, the committee was also told that there is room for improvement in the way the education system encourages 'entrepreneurial mindsets' in young people. Professor Milford, QUT, explained:

> *First of all, through what we do we find out that young kids are not, in my opinion, getting sufficiently exposed to the broad concepts of transformational things like AI and robots, even though there is a focus on coding, for example, which is really a method and most people will not end up coding but everyone will be exposed to AI, robotics and automation. The second thing is the entrepreneurial mindset of young kids. I know that a lot of people are doing a lot about this, but by the time they get to university a lot of the battles have been fought and won or lost around how entrepreneurial they are and how well people can adapt to non-traditional career pathways as well.*[339]

Professor Milford has developed an innovative range of books designed to introduce children to concepts like artificial intelligence and robots.[340]

The department highlighted the importance of raising awareness of non-traditional career pathways. For example, Ms Johnston stated:

> *One of the things that we became aware of through our consultation on the manufacturing roadmap is the perception that manufacturing does not offer significant career opportunities in this country. The perception is that manufacturing is all done offshore. Part of the manufacturing roadmap is about raising awareness that Queensland has expertise in manufacturing. Manufacturing does happen here within Queensland and we certainly have expertise. By changing that understanding you then also start to identify that there are opportunities for young people in manufacturing, and the nature of the roles is changing. It can be quite exciting, because it can be about robotics and automation and skills that are not traditionally associated with manufacturing careers.* [341]

In particular, the committee heard about the importance of raising awareness of these job opportunities for female students, with a view to increasing the engagement of women in STEM-related careers. The department provided some examples of the work it is progressing through the government's Women in Manufacturing program, such as networking and mentoring events and student participation in factory tours led by prominent women in advanced manufacturing. [342] Similarly, the Department of Education advised the committee that it is trying to attract more female students into subjects like mathematics, science and digital technologies, and that a significant component of this was assisting these students to envisage what future jobs could look like in these areas:

> *The purpose of the STEM camp was to get these young people to see what the future is for the training that they might do in that university or VET pathway. Our young people often have difficulty seeing from the classroom what the future jobs look like for them. Part of the girl camp is about getting those girls in front of a range of highly qualified women to be able to see that. That is one of our strategies. It is also about encouraging all of our students, regardless of whether they are young men or young women, into the STEM area.*[343]

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339 Professor Michael Milford, QUT, public hearing transcript, Brisbane, 16 November 2018, pp 48-49.

340 These include: 'Rachel the Rocketeer' and 'The Complete Guide to Artificial Intelligence for Kids', published at Store.MathThrills.com.

341 Ms Denise Johnston, DSDMIP, public briefing transcript, Brisbane, 15 October 2018, p 12.

342 DSDMIP, submission 16, pp11-12.

343 Ms Robyn Rosengrave, Department of Education, public briefing transcript, Brisbane, 12 November 2018, p 9. See also Queensland Government, Science Technology, Engineering and Mathematics, available at: www.education.qld.gov.au/curriculum/school-curriculum/stem

The committee heard that despite female participation in STEM throughout school, there were difficulties in retaining female students' interest in STEM related-fields as they progressed from secondary school to university. For example, Dr Keay, Australian Centre for Robotic Vision, explained:

> *…we cannot get girls to consider going into these areas. At the moment in Australia only 15 per cent of engineering students are female. That has not changed in 10 years. Despite the fact that we are putting in all of these fantastic STEM education programs, we are not seeing an increase in the number of women who are participating.*[344]

In regard to the way forward, Dr Keay suggested the publication of gender ratios in subjects across schools, similar to the Science in Australia Gender Equity initiative that universities have adopted:

> *Schools would already have data on the gender ratios in all of their subjects. I believe that should be made public. The reason for that is that I think you would have much more effective information sharing across schools and be able to see which schools are successful in maintaining a high cohort of female students in top level maths and science if we could see those numbers. Then parents could make a decision, if they have the opportunity to, as to where their daughters can access the best opportunities to pursue particularly STEM subjects. Schools that perhaps are not tracking as well can look to their peers and see what they are doing differently. Something has to change because those numbers, as I said, are not changing in terms of how many women we are getting into the area, and in areas like this where there are skills shortages that is a real problem.*[345]

Ms Starkey, CEO and founder of Ozius, explained that she had been involved in visiting schools and talking to students about technologies, including GPS, spatial systems and positioning systems. She explained that, in her view, to encourage females into STEM-related fields it is important to continuously engage and keep opportunities open:

> *I think that is where earth observation provides a really great channel for women. Typically in the past the only way to get into this field has been through more positioning and engineering and physics based sciences. We are starting to see a broader base of science, maths, engineering and technology that can actually enter this world. Keeping that engagement up has to be the key... It is not necessarily about blockages; it is just about opportunities. It is keeping those opportunities open and engagement at all levels*.[346]

The Department of Defence explained that more and more women are joining the Australian Defence Force, and noted their exceptional skill sets and ability. The committee heard of the importance of promoting these options to females and demonstrating to them they are of great benefit to STEM-related fields.[347]

The committee heard that whilst it is important for Queensland to continue its momentum on STEM and encouragement of STEM-related careers by telling the inspirational story of space, it will be equally important to ensure that job opportunities will be there when students finish university:

> *There is quite a level of excitement in people around the age of 16, 17 at the moment around having a career in space in the future. I hope that we are not going to let them down with the*

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344 Dr Sue Keay, Australian Centre for Robotic Vision, public hearing transcript, Brisbane, 16 November 2018, p 48.

345 Dr Sue Keay, Australian Centre for Robotic Vision, public hearing transcript, Brisbane, 16 November 2018, p 48.

346 Ms Alisa Starkey, Ozius, public hearing transcript, Brisbane, 1 February 2019, p 21.

347 Air Marshal Warren McDonald, ASM, CSC, Department of Defence, public hearing transcript, Brisbane, 1 February 2019, p 6.

rhetoric that we are talking about with space—that there will be job opportunities in four or five years time for them when they go through these degrees…

I am hoping that we can grow the sector and, therefore, the people who are coming in and doing university degrees in science, engineering, maths and the like will all have jobs in the future.[348]

Committee comment

The committee acknowledges the importance of STEM education in all areas of the space supply chain and considers that Queensland's education system is well-placed to prepare students for careers in the space industry.

The committee heard evidence throughout the inquiry of the importance of maintaining focus on STEM in schooling and encourages the Queensland Government to continue its commitment to STEM learning from an early age. Further, the committee encourages the Department of Education and the Department of State Development, Manufacturing, Infrastructure and Planning to continue to work together to ensure that students, particularly females, are aware of the career opportunities that STEM offers, including those within the developing space sector.

Recommendation 13

The committee recommends the Queensland Government continue to encourage all students to study STEM subjects and maintain its commitment to compulsory mathematics in secondary school.

Recommendation 14

The committee recommends the Queensland Government continue to promote female participation in STEM, including through proactive targeted engagement between secondary schools and female students, and their families, who have demonstrated capabilities in STEM.

Recommendation 15

The committee recommends the Department of State Development, Manufacturing, Infrastructure and Planning provide the committee with an update of the Queensland Government's progress against all recommendations contained within this report in November 2019.

[348] Dr Andrew Dowse AO, Air Vice-Marshal (Retired), Director of Defence Research and Engagement at Edith Cowan University, public hearing transcript, Brisbane, 1 February 2019, p 15.

Appendix A – Submitters

Sub #	*Submitter*
1	*Confidential*
2	Remote Area Planning and Development Board
3	Digital Globe
4	Defence Materials Technology Centre
5	CSIRO
6	Earth Observation Australia
7	Products for Industry
8	Space Industry Association of Australia
9	Rhonda O'Sullivan
10	Professor Stuart Phinn
11	Confidential
12	James Minchinton
13	Professor Michael Smart
14	Black Sky Aerospace
15	Australia Space Launch
16	Department of State Development, Manufacturing, Infrastructure and Planning
17	Teakle Composites
18	Professor Peter Schubel
19	Equatorial Launch Australia
20	International Aerospace Law and Policy Group
21	Australian Space Agency
22	Dr Ingo Jahn
23	Boeing
24	Pam Melroy
25	NEO Resource Atlas Pty Ltd
26	Moonshoot

Appendix B – Officials at public briefings

Brisbane - 15 October 2018

Department of State Development, Manufacturing, Infrastructure and Planning

- Ms Denise Johnston, Executive Director, Defence Industries Queensland
- Mr Lau Saili, Director of Strategy and Governance, Defence Industries Queensland
- Ms Rita Borzelleca, Manager, Defence Industries Queensland

Department of Natural Resources, Mines and Energy

- Mr Steve Jacoby, Executive Director, Land and Spatial Information

Brisbane - 12 November 2018

Department of Education

- Ms Robyn Rosengrave, Executive Director, Curriculum, Teaching and Learning, State Schools

Department of Employment, Small Business and Training

- Mr Steve Koch, Deputy Director-General, Strategic Policy and Employment
- Mr Tim Maloney, Director, Strategic Engagement

Appendix C – Witnesses at public hearings

Brisbane – 19 October 2018

- Professor Michael Smart, Chair of Hypersonic Propulsion, School of Mechanical and Mining Engineering, University of Queensland
- Dr David Williams, Executive Director, Digital, National Facilities and Collections, CSIRO
- Professor Stuart Phinn, Professor of Geography, University of Queensland; and Director, Earth Observation Australia
- Mr Nick Green, General Manager, Defence and Aerospace, Special Projects, Products for Industry
- Air Vice-Marshal (Retired) Neil Hart, Strategic Defence Adviser, Department of State Development, Manufacturing, Infrastructure and Planning; Chair Queensland Space Industry Reference Group
- Ms Denise Johnston, Executive Director, Defence Industries Queensland, Department of State Development, Manufacturing, Infrastructure and Planning
- Dr Jason Armstrong, Senior Manager, Brisbane Technology Centre, Boeing Research and Technology Australia

Brisbane – 16 November 2018

- Mr Anthony Murfett, Deputy Head, Australian Space Agency
- Mr Adam Gilmour, CEO and Founder, Gilmour Space Technologies
- Mr Blake Nikolic, Director, Black Sky Aerospace Pty Ltd
- Mr Peter Kinne, Regional Director, Australasia, DigitalGlobe
- Mr Duncan Blake, Space Law and Strategy Consultant, International Aerospace Law & Policy Group
- Mr Joseph Wheeler, Principal, International Aerospace Law & Policy Group
- Dr Sue Keay, Chief Operating Officer, Australian Centre for Robotic Vision
- Professor Michael Milford, School of Electrical Engineering and Computer Science, QUT

Brisbane – 1 February 2019

- Air Marshal Warren McDonald, AM, CSC, Chief of Joint Capabilities, Joint Capabilities Group, Department of Defence (via teleconference)
- Dr Andrew Dowse AO, Air Vice-Marshal (Retired), Director, Defence Research and Engagement, Edith Cowan University (via teleconference)
- Ms Alisa Starkey, Founder and CEO, Ozius Pty Ltd
- Dr Sandy Tirtey, Director of Business Development Australia and Launch Director, Rocket Lab

Appendix D – List of companies in the space sector with a significant presence in Queensland

Absolute Data Group

Airbus

BAE Systems

Black Sky Aerospace

Boeing Defence Australia

Crystalaid Manufacture

DigitalGlobe

Elbit Systems of Australia

EM Solutions

Esri Australia

Ferra Engineering

Gilmour Space Technologies

Harris Corporation

Heat Treatment Australia

Hypersonix

Imagus

ImmersaView

Insitu Pacific

Intellidesign

L3 Micreo

Lavender Composites

Northrop Grumman

Nova Systems

Ozius

Products for Industry

Qantas

QinetiQ

Raytheon

Teakle Composites

Teledyne Australia